



US008044759B2

(12) **United States Patent**
Yang et al.

(10) **Patent No.:** **US 8,044,759 B2**
(45) **Date of Patent:** **Oct. 25, 2011**

(54) **OVERLAPPING COMPACT MULTIPLE TRANSFORMERS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/902,940**

(22) Filed: **Oct. 12, 2010**

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(65) **Prior Publication Data**

US 2011/0043316 A1 Feb. 24, 2011

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/970,995, filed on Jan. 8, 2008, now Pat. No. 7,812,701.

(51) **Int. Cl.**
H01F 5/00 (2006.01)

(52) **U.S. Cl.** **336/200**

(58) **Field of Classification Search** 336/65,
336/200, 232, 180–184, 173, 170; 330/295,
330/195, 124 R

See application file for complete search history.

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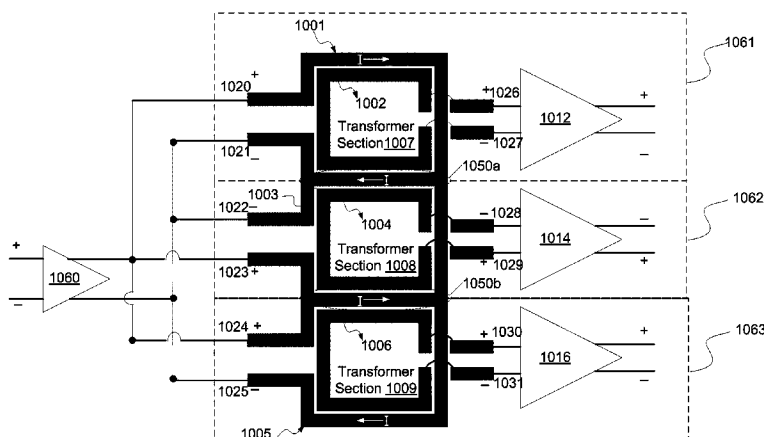
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(57) **ABSTRACT**

Systems and methods are provided for overlapping compact multiple transformers. The systems and methods may include a first transformer section that includes a first primary winding section and a first secondary winding, where the first primary winding section is inductively coupled to the first secondary winding, where the first transformer section is associated with a first rotational current flow direction in the first primary winding section; and a second transformer section that includes a second primary winding section and a second secondary winding, where the second primary winding section is inductively coupled to the second secondary winding, wherein the second transformer section is associated with a second rotational current flow direction in the second primary winding section, where a first portion of the first primary winding section is adjacent to a second portion of the second primary winding section, where the adjacent first and second portions include a substantially same first linear current flow direction.

20 Claims, 15 Drawing Sheets



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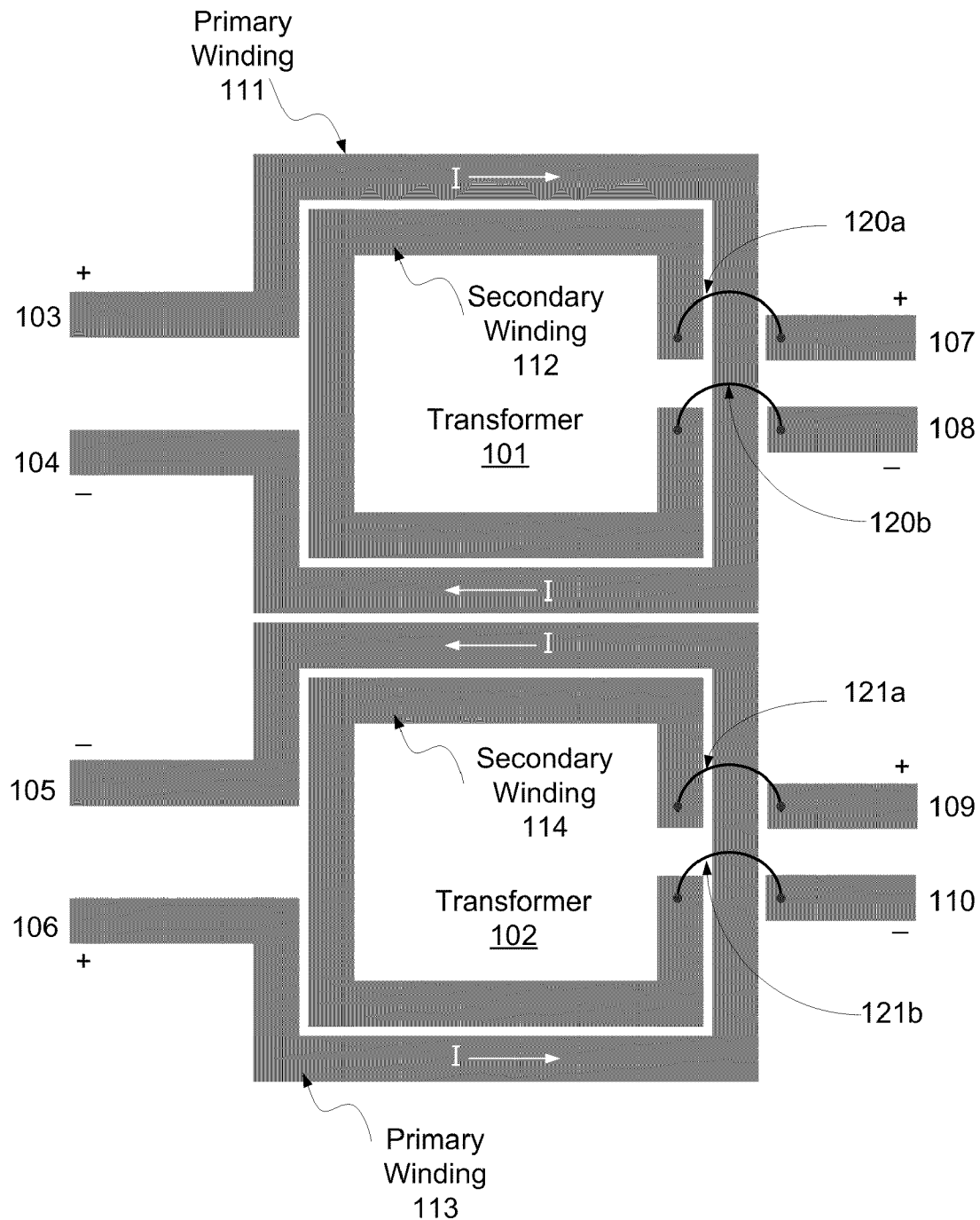


FIG. 1A

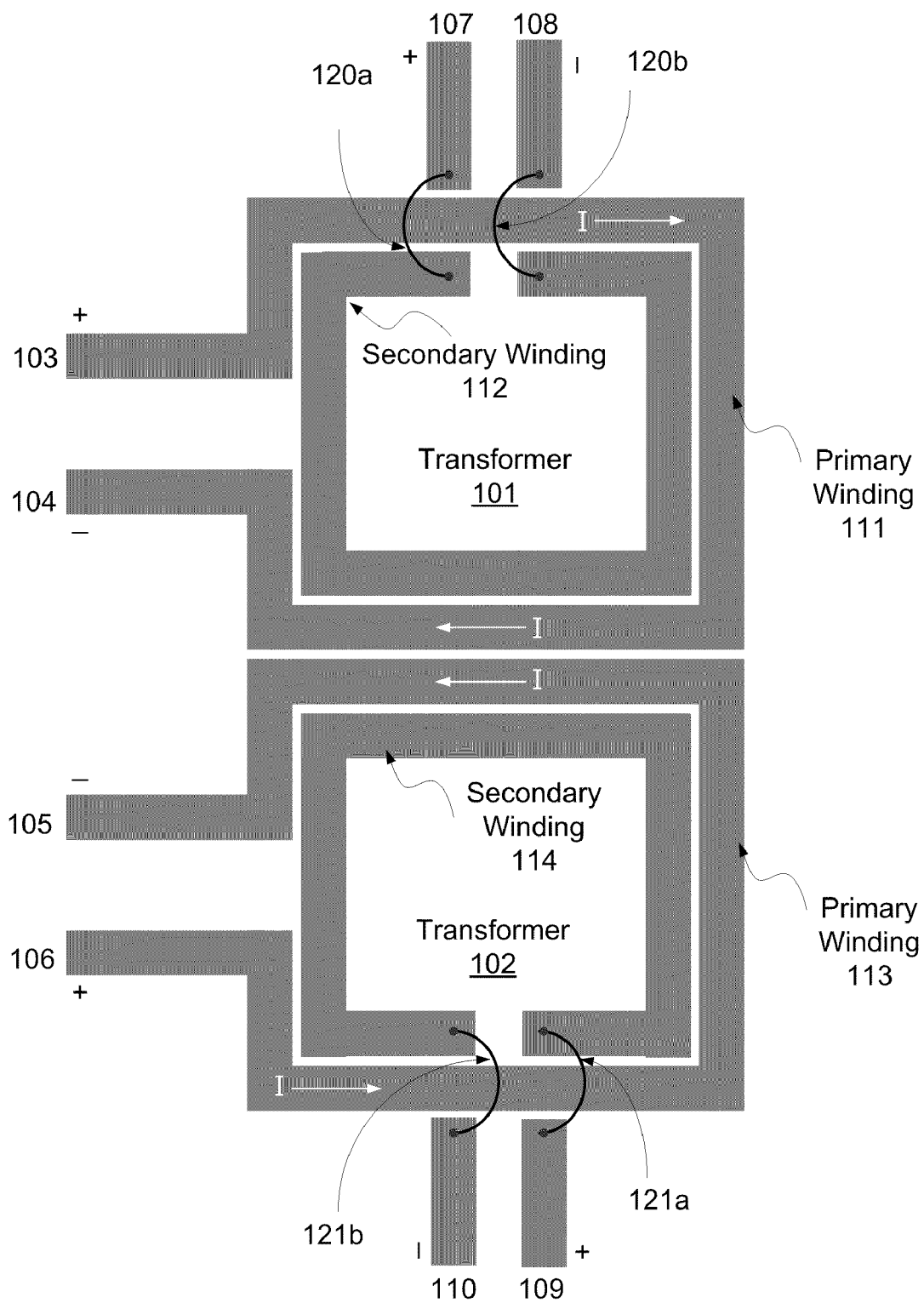


FIG. 1B

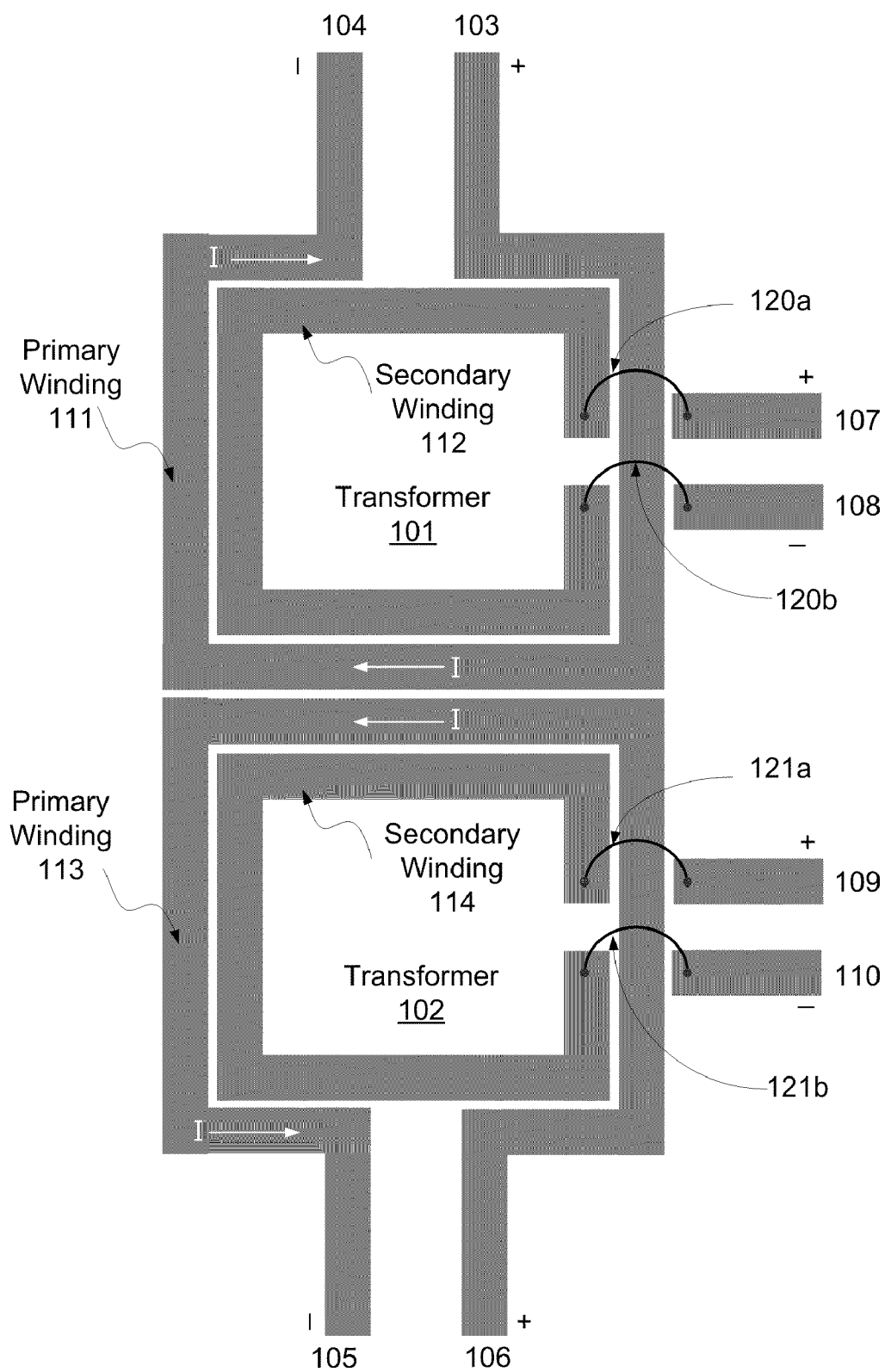


FIG. 1C

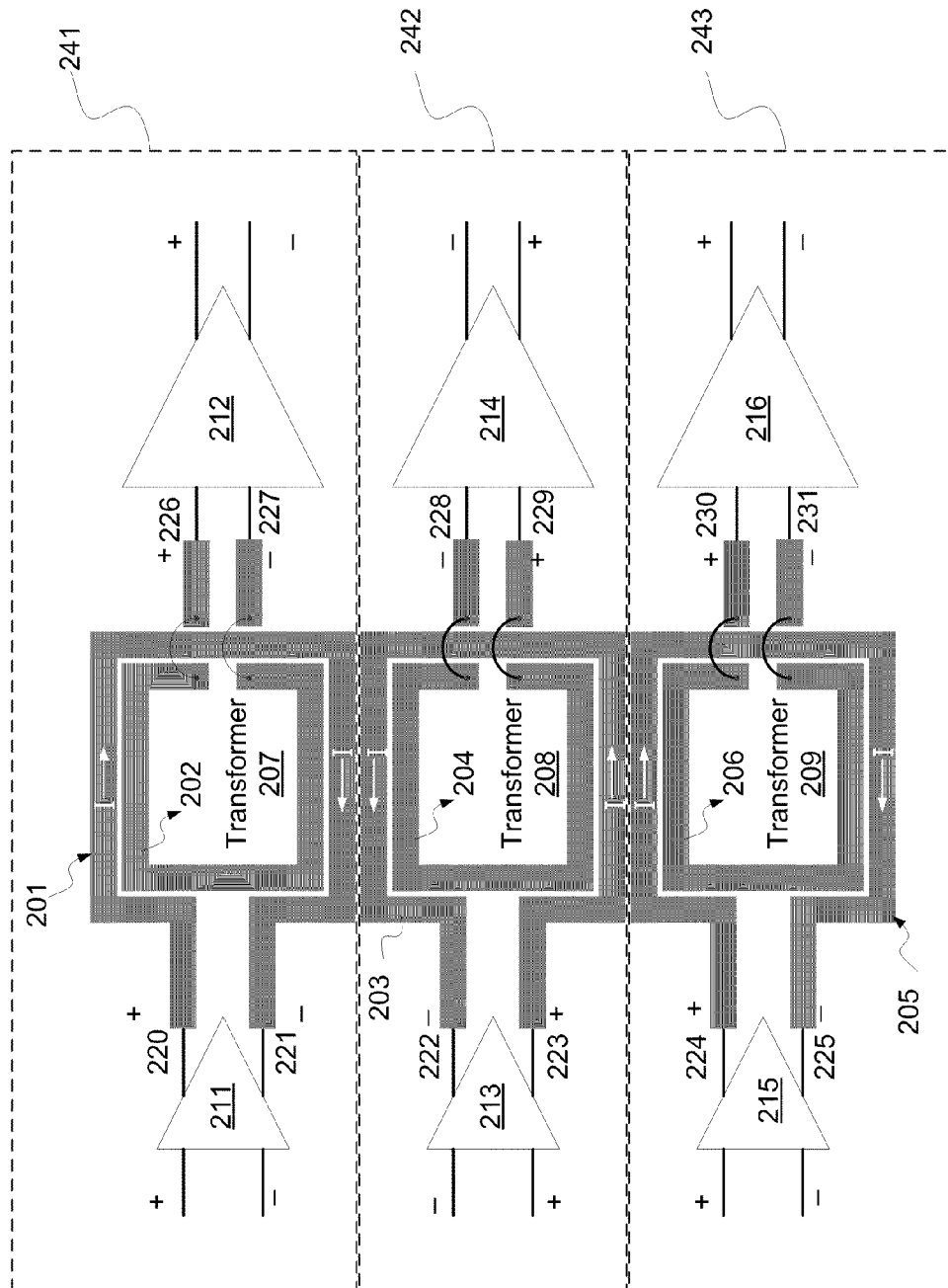


FIG. 2

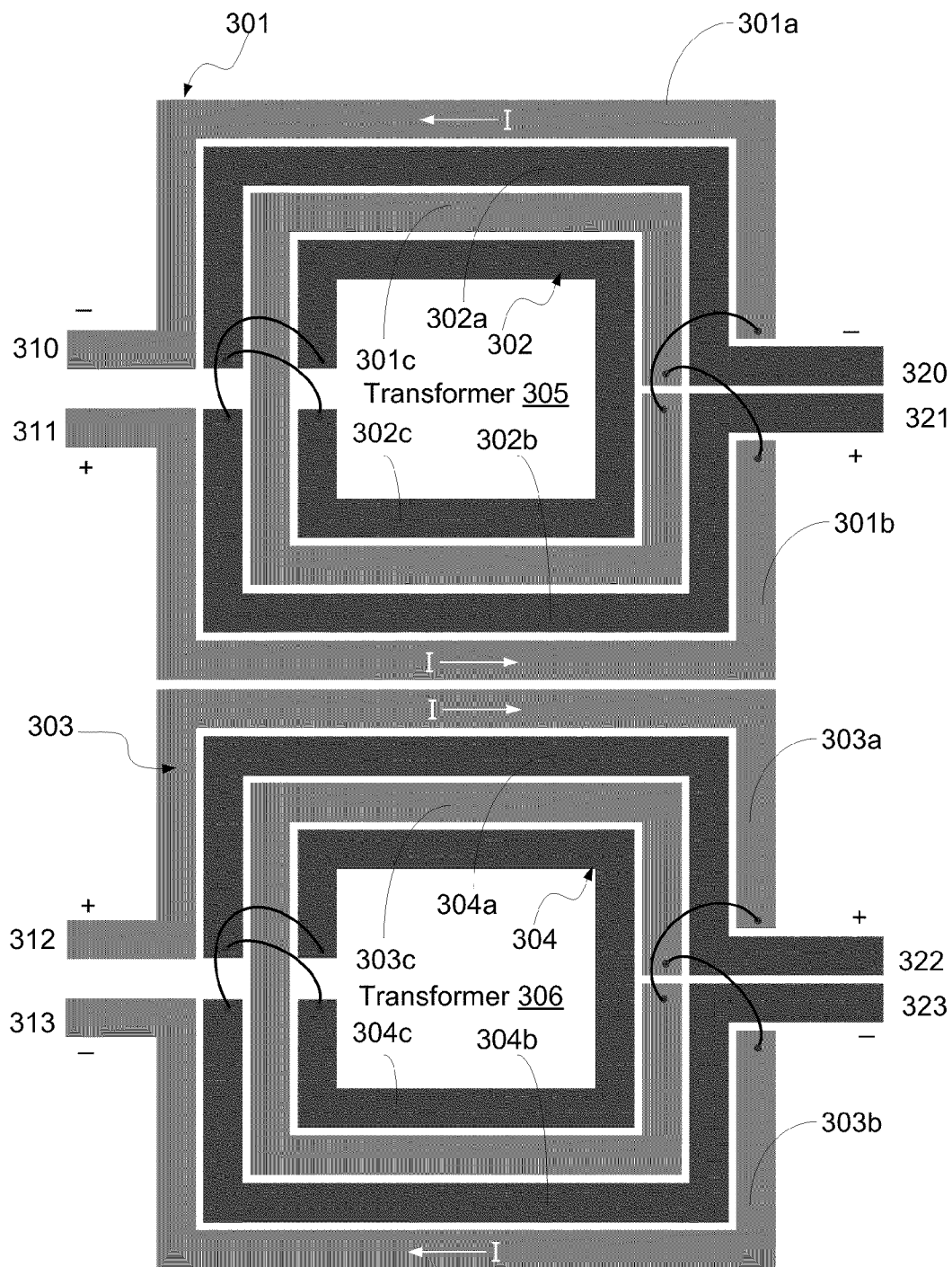


FIG. 3

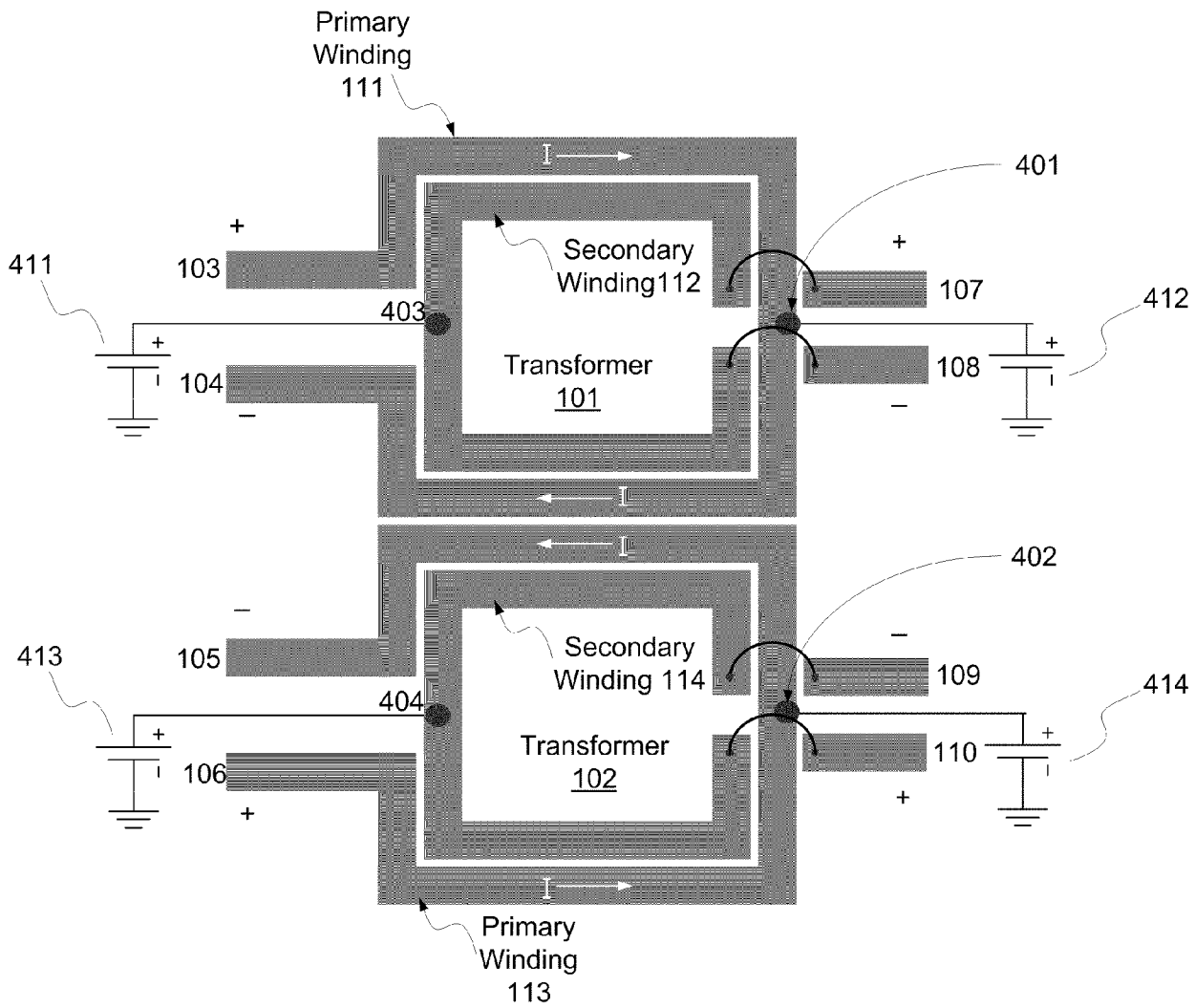


FIG. 4

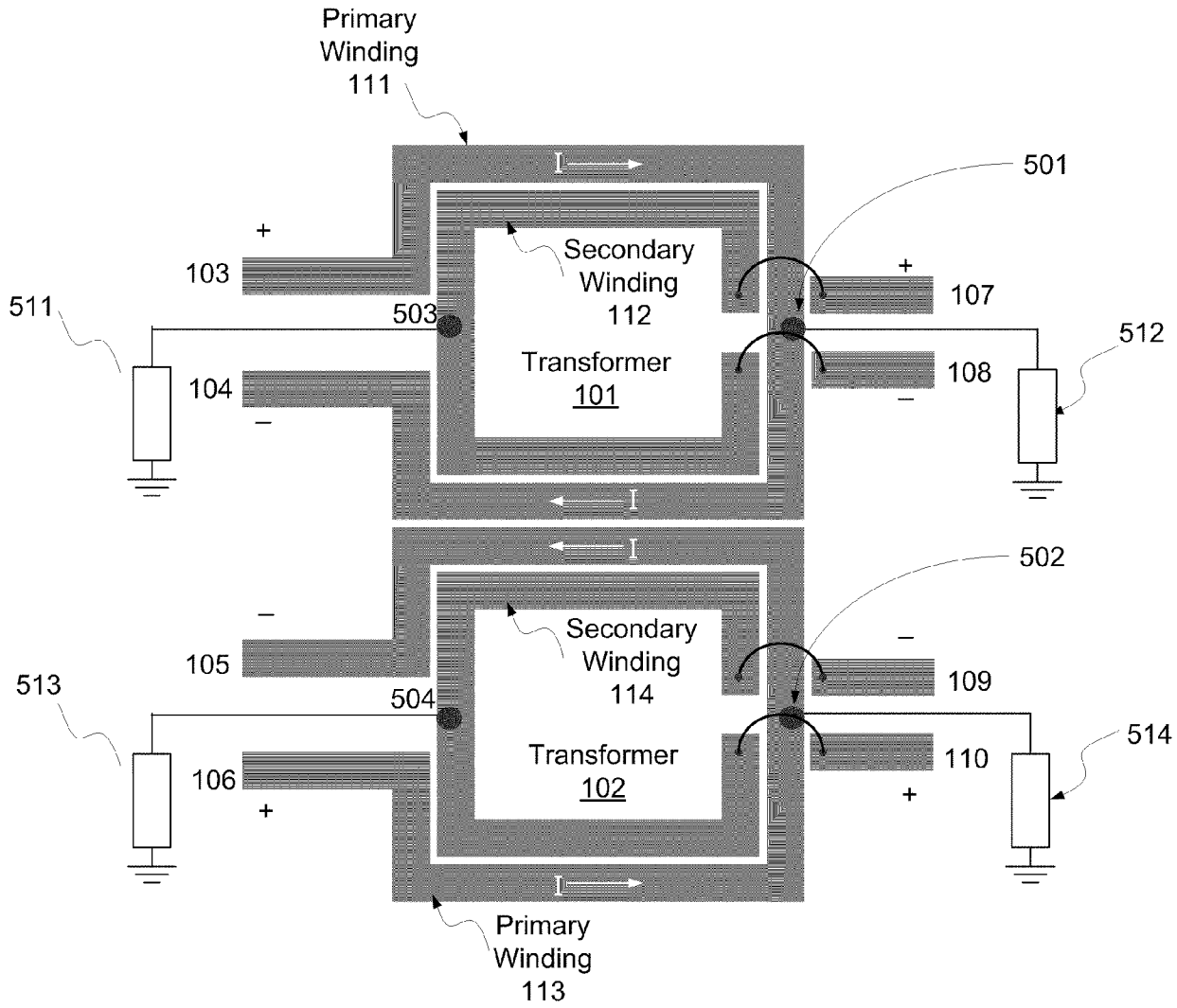


FIG. 5

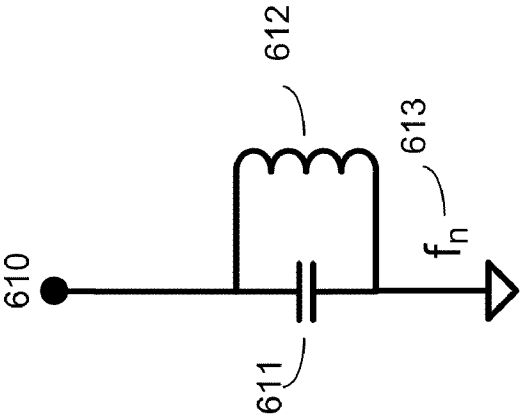


FIG. 6B

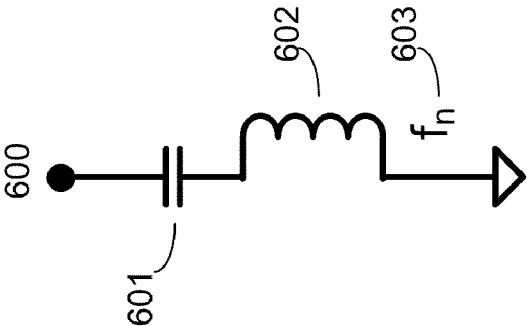


FIG. 6A

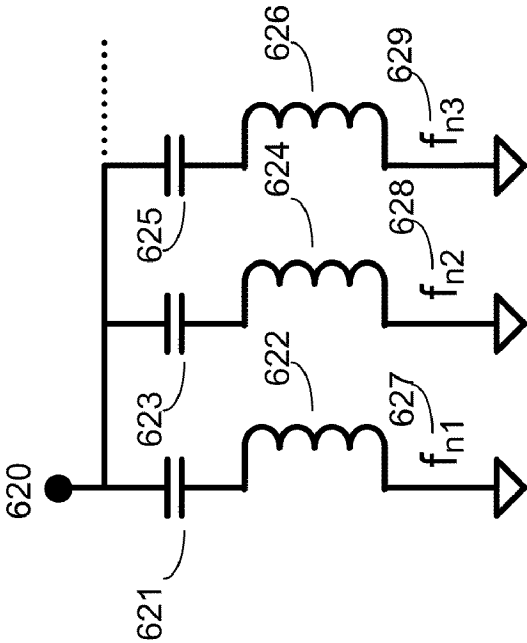


FIG. 6C

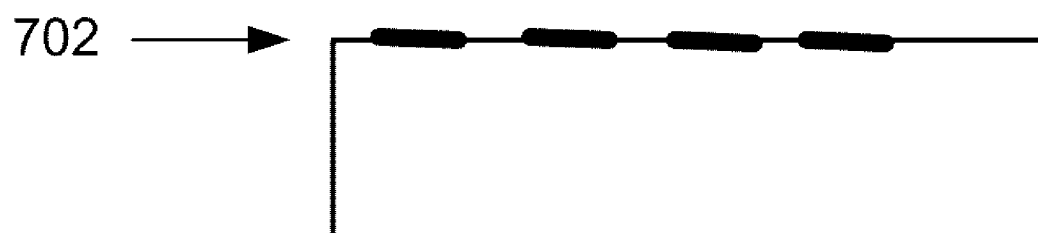


FIG. 7

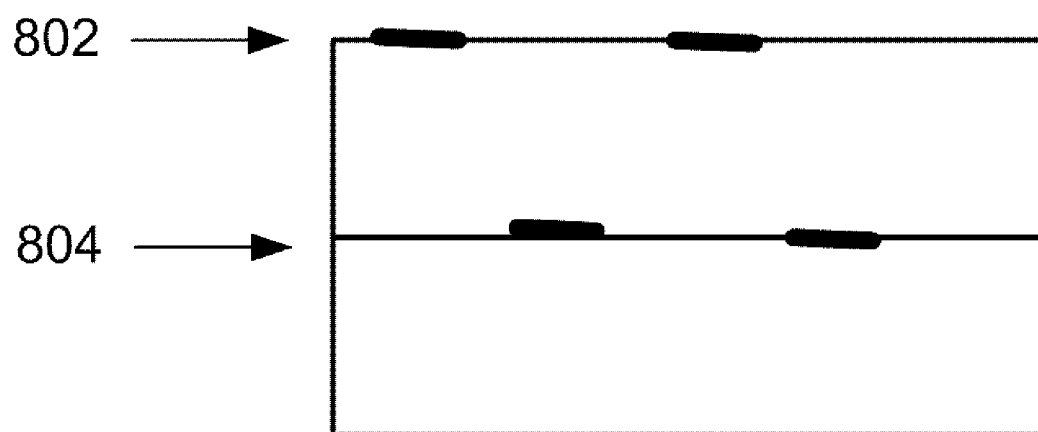


FIG. 8

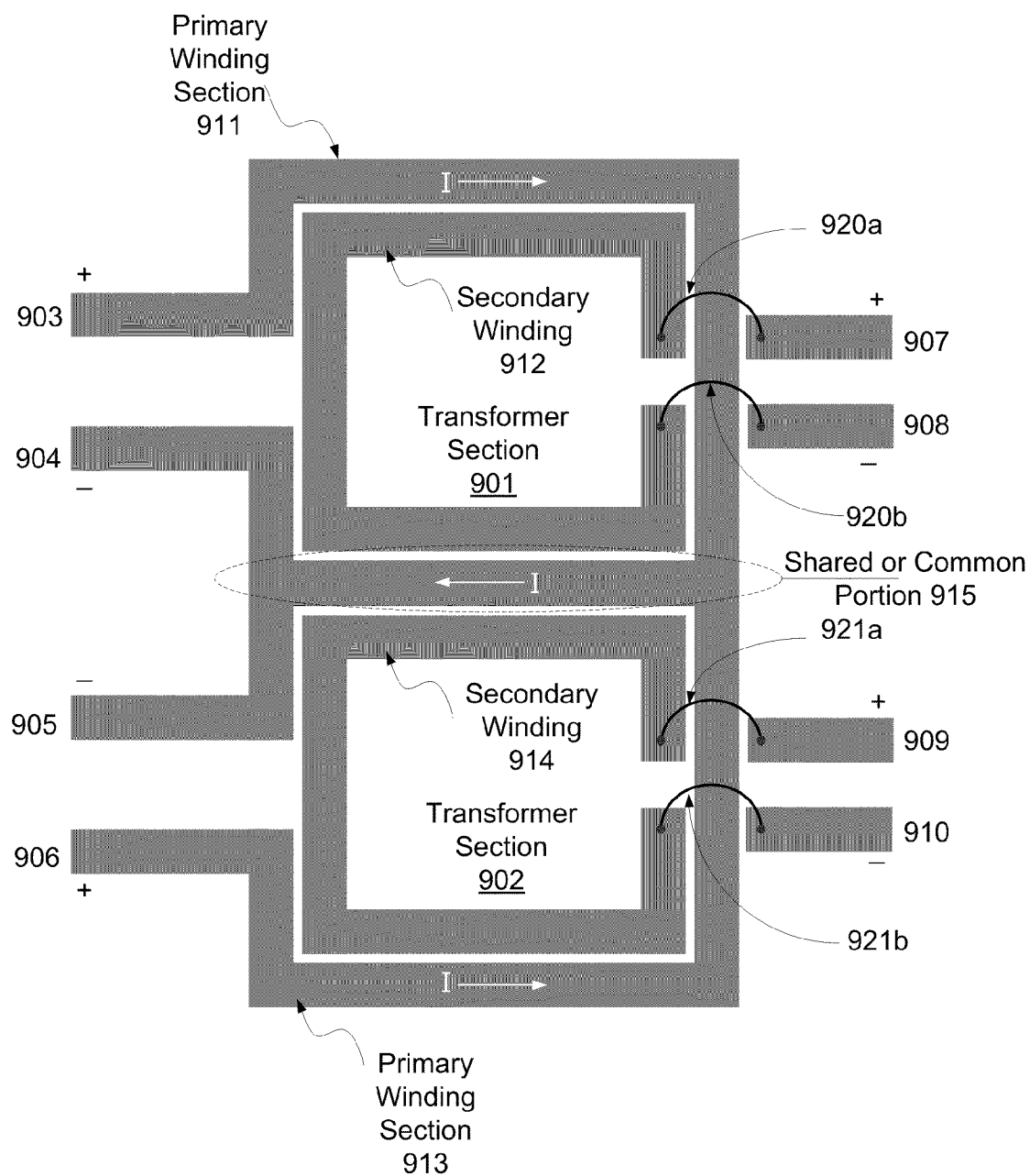


FIG. 9A

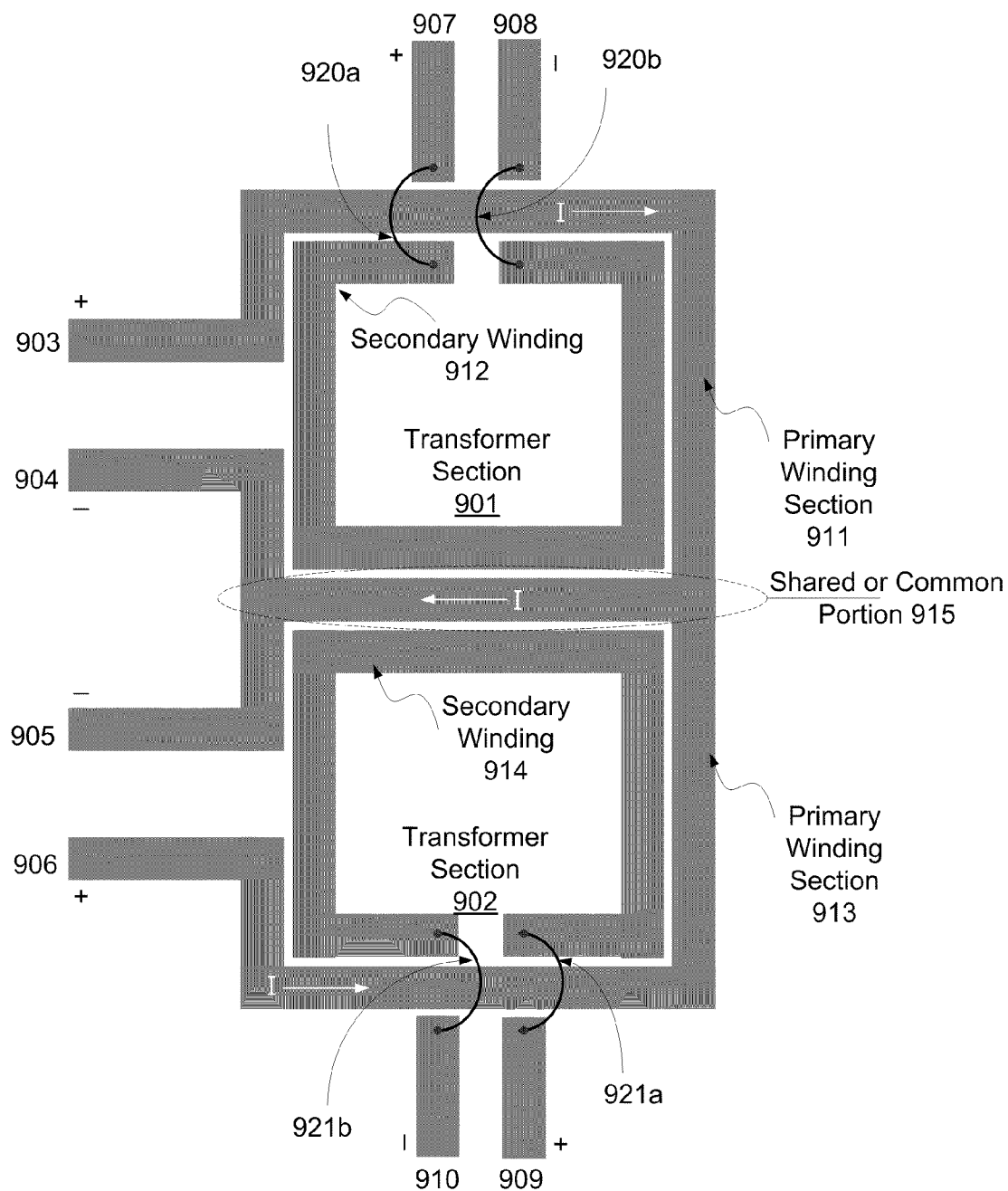


FIG. 9B

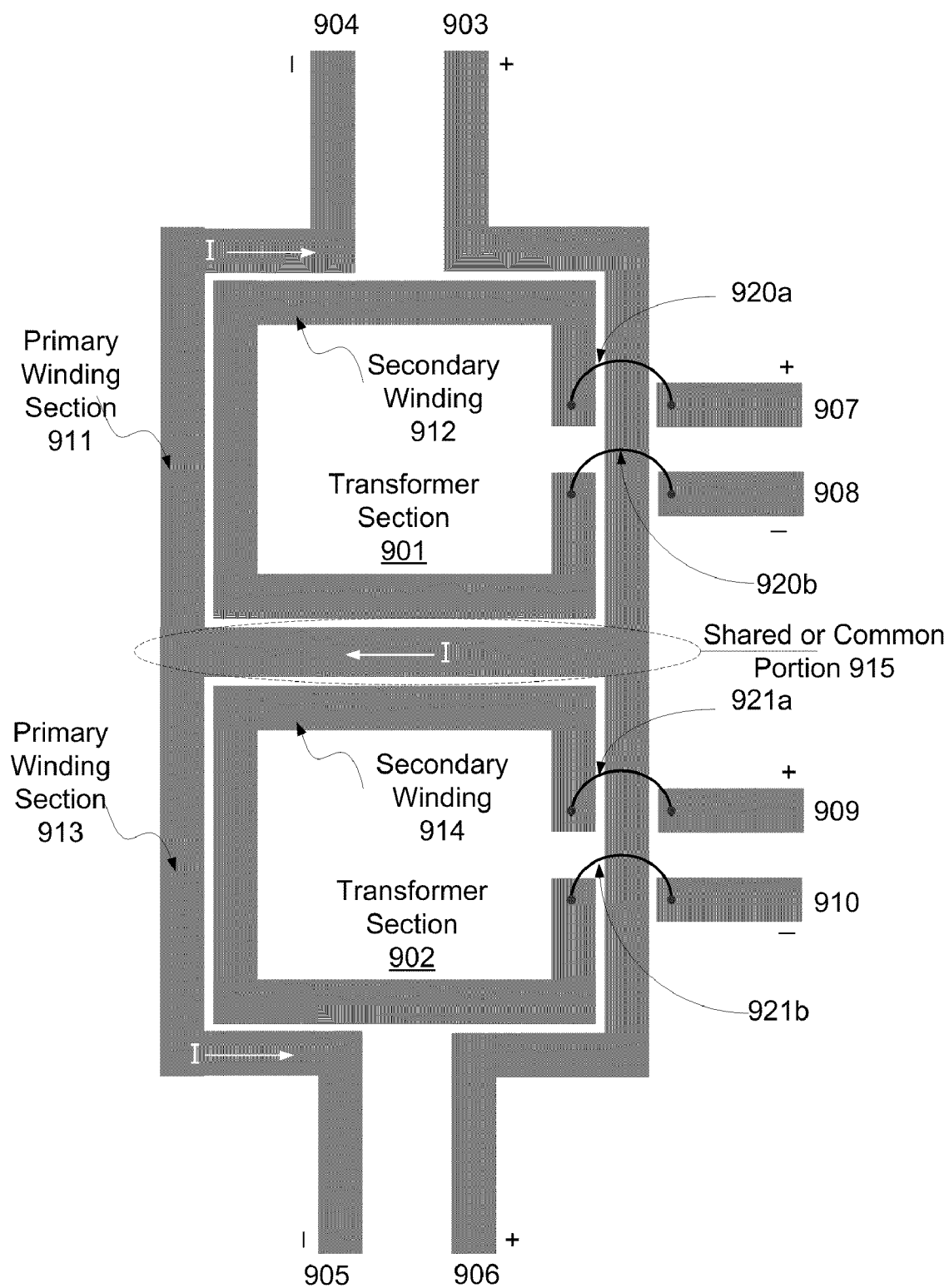


FIG. 9C

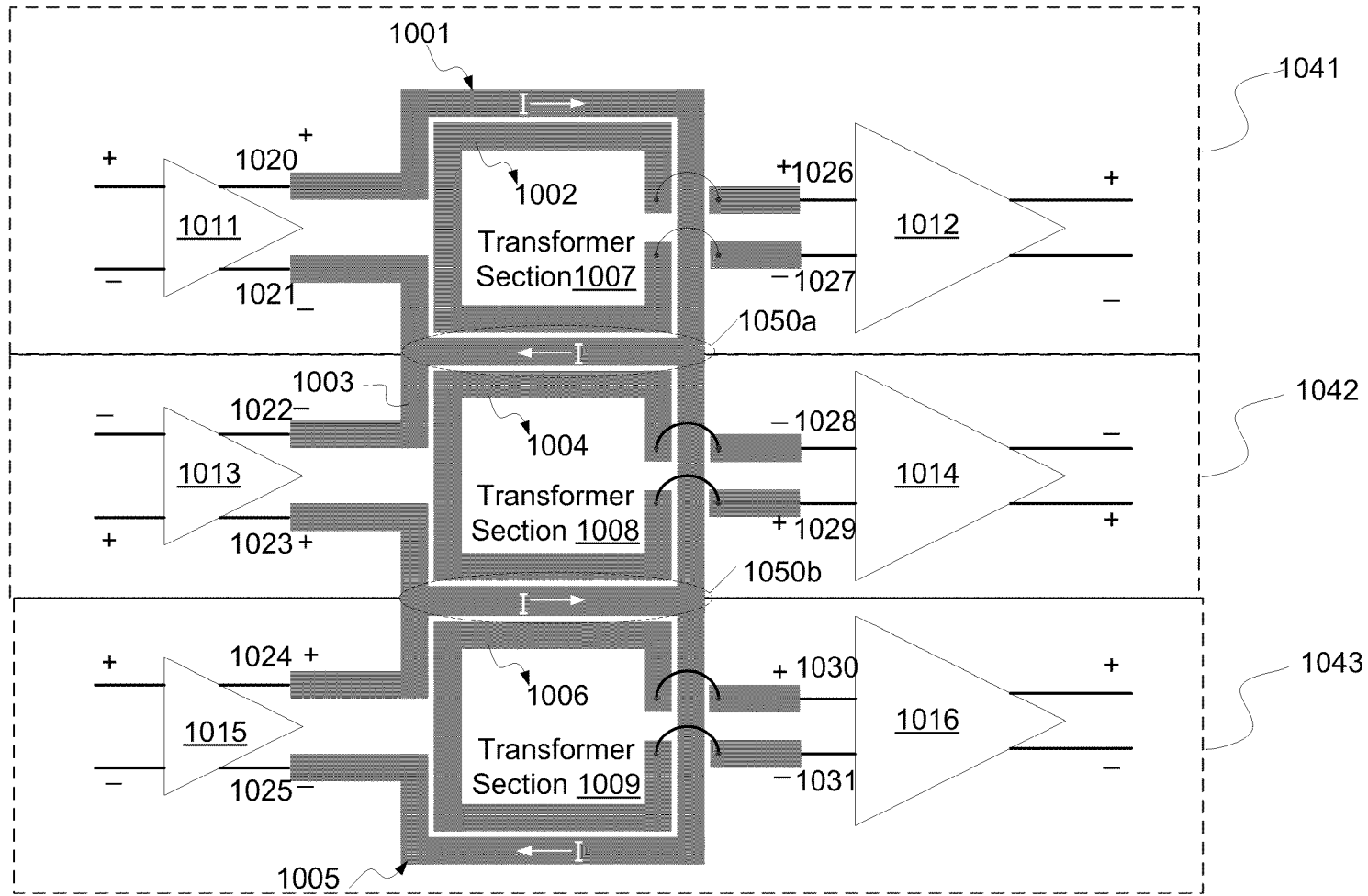


FIG. 10A

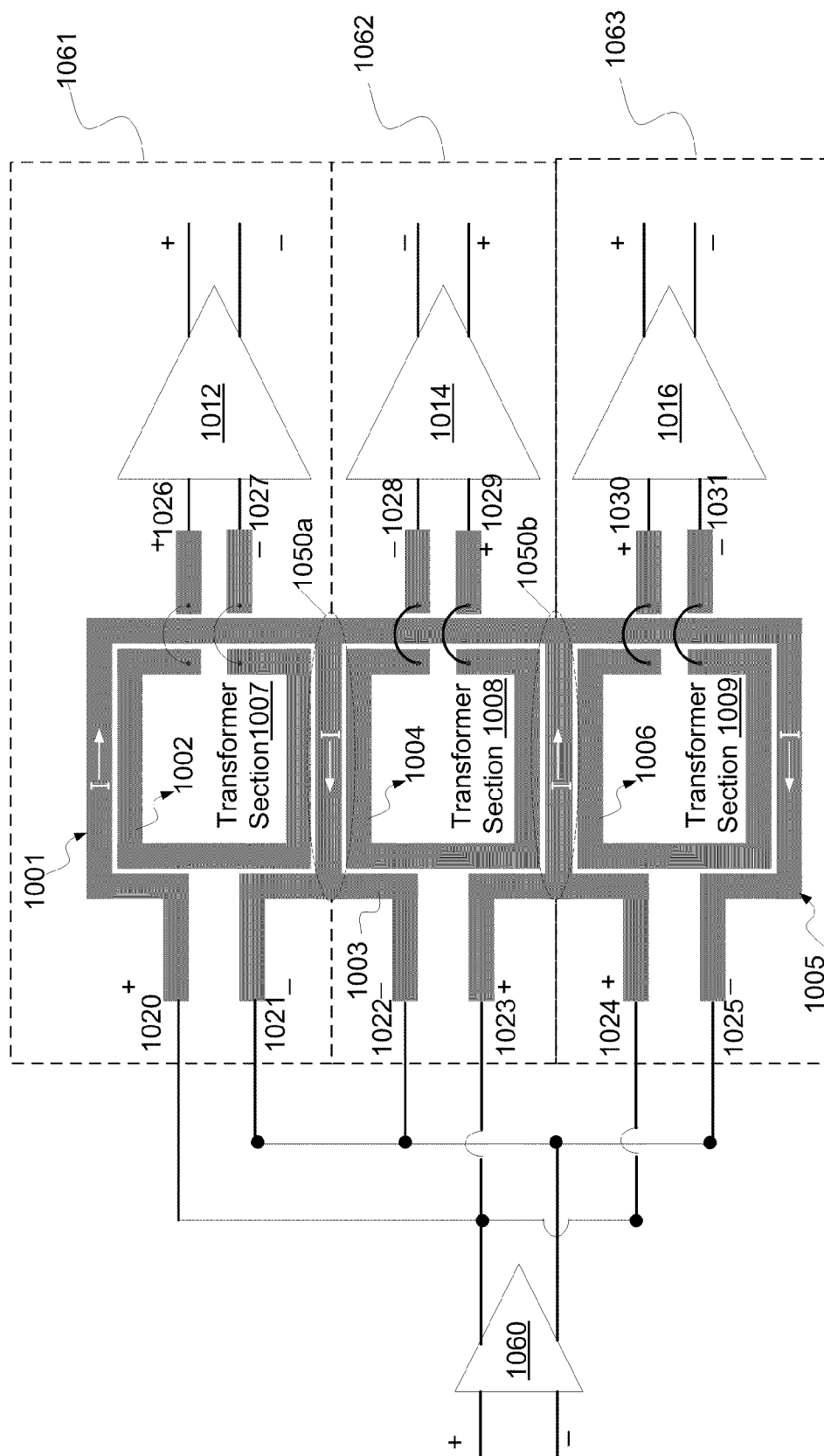


FIG. 10B

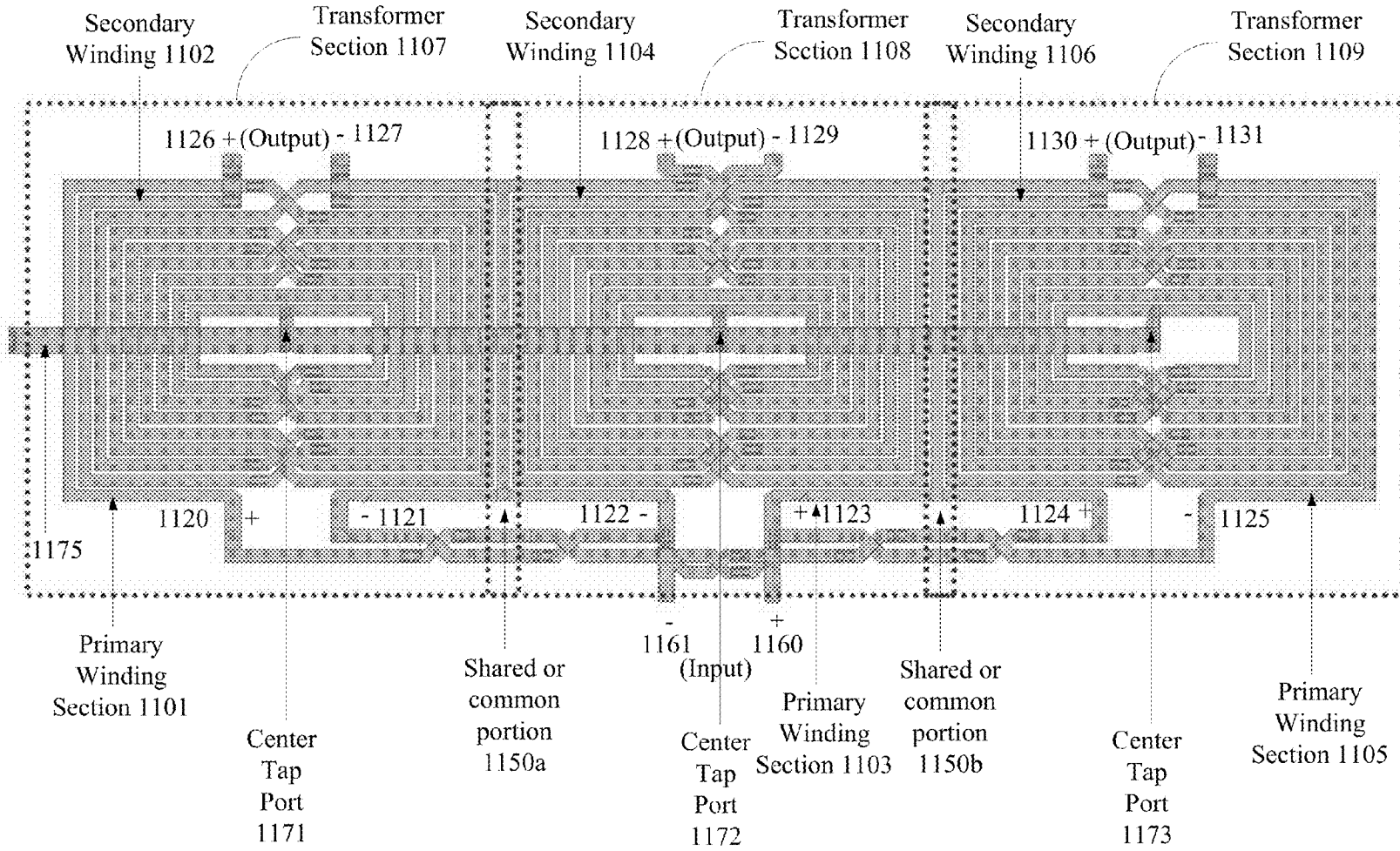


FIG. 11

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OVERLAPPING COMPACT MULTIPLE TRANSFORMERS

RELATED APPLICATION

The present application is a continuation-in-part of U.S. Non-provisional application Ser. No. 11/970,995, filed on Jan. 8, 2008, and entitled "Compact Multiple Transformers," which is hereby incorporated by reference in its entirety as if fully set forth herein.

FIELD OF INVENTION

The invention relates generally to transformers, and more particularly, to systems and methods for overlapping compact multiple transformers.

BACKGROUND OF THE INVENTION

According to the fast growth of semiconductor technology, many blocks and functions have been integrated on a chip as a System-On-Chip (SOC) technology. In the semiconductor technology, a monolithic transformer requires a significant amount of space. Moreover, the monolithic transformer requires a minimum of 50- μ m spacing from other circuitry to prevent undesirable magnetic coupling or loss of magnetic flux. Accordingly, the total size of multiple transformers is large and increases manufacturing cost, chip size, and package size.

BRIEF SUMMARY OF THE INVENTION

According to an example embodiment of the invention, there may be system for multiple transformers. The system may include a first transformer section that includes a first primary winding section and a first secondary winding, wherein the first primary winding section is inductively coupled to the first secondary winding, wherein the first transformer section is associated with a first rotational current flow direction in the first primary winding section; and a second transformer section that includes a second primary winding section and a second secondary winding, wherein the second primary winding section is inductively coupled to the second secondary winding, wherein the second transformer section is associated with a second rotational current flow direction opposite the first rotational current flow direction in the second primary winding section, wherein a first portion of the first primary winding section is adjacent to a second portion of the second primary winding section, wherein the adjacent first and second portions include a substantially same first linear current flow direction.

According to another example embodiment of the invention, there may be a method for providing multiple transformers. The method may include providing a first transformer section that includes a first primary winding section and a first secondary winding, wherein the first primary winding is inductively coupled to the first secondary winding, wherein the first primary winding is coupled to one or more first input ports; receiving a first input source at the one or more first input ports to provide a first rotational current flow direction in the first primary winding; providing a second transformer section that includes a second primary winding section and a second secondary winding, wherein the second primary winding section is inductively coupled to the second secondary winding, wherein the second primary winding is coupled to one or more second input ports; receiving a second input source at the one or more second input ports to provide a

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second rotational current flow direction opposite the first rotational current flow direction in the second primary winding section; and positioning a first portion of the first primary winding section adjacent to a second portion of the second primary winding section, wherein the adjacent first and second portions include a substantially same first linear current flow direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIGS. 1A-1C illustrates example compact multiple transformers, according to an example embodiments of the invention.

FIG. 2 illustrates an example compact multiple transformers application for parallel inter-stage networks using multiple transformers, according to an example embodiment of the invention.

FIG. 3 illustrates example compact multiple transformers having one or more windings with multiple turns, according to an example embodiment of the invention.

FIG. 4 illustrates example compact multiple transformers with DC biasing through center taps, according to an example embodiment of the invention.

FIG. 5 illustrates example compact multiple transformers with tuning blocks through center taps, according to an example embodiment of the invention.

FIG. 6A-6C illustrate example schematic diagrams of example tuning blocks in accordance with example embodiments of the invention.

FIG. 7 illustrates an example planar structure for implementing the multiple transformers, according to an example embodiment of the invention.

FIG. 8 illustrates an example stacked structure for implementing the multiple transformers, according to an example embodiment of the invention.

FIGS. 9A-9C illustrate several example embodiments of overlapping compact multiple transformers, according to an example embodiment of the invention.

FIGS. 10A and 10B illustrate example applications for overlapping multiple transformers, according to an example embodiment of the invention.

FIG. 11 illustrates an example system for overlapping multiple transformers, according to an example embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Example embodiments of the invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

FIG. 1A illustrates example compact multiple transformers, including a first transformer **101** and a second transformer **102**, according to an example embodiment of the invention. As shown in FIG. 1A, the example compact multiple transformers may include a first transformer **101** that includes a primary winding **111** and a secondary winding **112**. The primary winding **111** may receive input signals from a first input port **103** that may receive a positive input signal

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and a second input port **104** that may receive a negative input signal. According to an example embodiment of the invention, the primary winding **111** may be inductively coupled to the secondary winding **112**. The secondary winding **112** may provide output signals to a first output port **107** providing a positive output signal and a second output port **108** providing a negative output signal. As shown in FIG. 1A, the outer primary winding **111** may encapsulate or surround one or more portions of the inner secondary winding **112**. One or more wire-bond, via, or other electrical connections **120a**, **120b** may be used to route the output ports **107**, **108** of the secondary winding **112** around the primary winding **111**. For example, connection **120a** may be used to electrically connect a first portion of the secondary winding **112** to the first output port **107**, and connection **120b** may be used to electrically connect a second portion of the secondary winding **112** to the second output port **108**.

Similarly, the example compact multiple transformers of FIG. 1A may also include a second transformer **102** that may include a primary winding **113** and a secondary winding **114**. The primary winding **113** may receive input signals from a first input port **105** that may receive a negative input signal and a second input port **106** that may receive a positive input signal. According to an example embodiment of the invention, the primary winding **113** may be inductively coupled to the secondary winding **114**. The secondary winding **114** may provide output signals to a first output port **109** providing a positive signal output and a second output port **110** providing a negative signal output. As shown in FIG. 1A, the outer primary winding **113** may encapsulate or surround one or more portions of the inner secondary winding **114**. One or more wire-bond, via, or other electrical connections **121a**, **121b** may be used to route the output ports **109**, **110** of the secondary winding **114** around the primary winding **113**. For example, connection **121a** may be used to electrically connect a first portion of the secondary winding **114** to the first output port **109**, and connection **121b** may be used to electrically connect a second portion of the secondary winding **114** to the second output port **110**.

According to an example embodiment of the invention, the first transformer **101** and the second transformer **102** may be spiral-type transformers, although other types of transformers may be utilized as well. It will also be appreciated that the primary windings **111**, **113** and the secondary windings **112**, **114** may be fabricated or otherwise patterned as conductive lines or traces using one or more metal layers provided on one or more semiconductor substrates. As an example, the metal layers may be comprised of copper, gold, silver, aluminum, nickel, a combination thereof, or yet other conductors, metals, and alloys, according to an example embodiment of the invention. According to an example embodiment of the invention, the transformers **101**, **102** may be fabricated with other devices on the same substrate. For example, transistors, inductors, capacitors, resistors, and transmission lines may be fabricated with the transformers **101**, **102** on the same substrate.

In FIG. 1A, the first transformer **101** and the second transformer **102** may be placed adjacent to each other according to a compact layout, according to an example embodiment of the invention. For example, a first section (e.g., a bottom section) of the primary winding **111** may be placed adjacent to a second section (e.g., a top section) of the primary winding **113** with a small separation distance. According to an example embodiment of the invention, the separation distance between the first section of the primary winding **111** and the adjacent second section of the primary winding **113** may be less than 50 μm , perhaps in the range of minimum spacing

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to 15 μm (e.g., perhaps 0.01-6 μm) for a highly compact layout or in the range of 15-30 μm (e.g., perhaps 12-14 μm) for a slightly less compact layout. Other spacing ranges may also be utilized without departing from example embodiments of the invention.

As shown in FIG. 1A, when the bottom section of the primary winding **111** is adjacent to the top section of the primary winding **113**, the linear direction of the current flow through the adjacent primary winding sections may be provided in the same linear direction in order to magnetically couple the first transformer **101** to the second transformer **102** through the adjacent primary winding sections. In order for the adjacent primary winding sections to have the substantially the same linear current flow direction, the rotational current flow in the primary winding **111** may be provided in a first rotational direction while the rotational current flow in the primary winding **113** may be provided in a second rotational direction that is different from or opposite the first rotational direction. For example, by providing the primary winding **111** with a clockwise rotational current flow direction, the linear current flow in the bottom section of the primary winding **111** may be a right-to-left linear current flow direction. The adjacent top section of the primary winding **113** may likewise be provided with a right-to-left linear current flow direction by providing the primary winding **113** with a counterclockwise rotational current flow direction.

To provide the primary winding **111** with the clockwise rotational current flow direction, the first input port **103** may be provided with a positive input signal and the second input port **104** may be provided with a negative input signal, according to an example embodiment of the invention. On the other hand, to provide the primary winding **105** with the counterclockwise rotational current flow direction, the first input port **105** may be provided with a negative input signal and the second input port **106** may be provided with a positive input signal, according to an example embodiment of the invention.

In FIG. 1A, both the input ports **103**, **104** for the first transformer **101** as well as the input ports **105**, **106** for the second transformer **102** may be located on a left side of a compact layout according to an example embodiment of the invention. The output ports **107**, **108** for the first transformer **101** as well as the output ports **109**, **110** for the second transformer **102** may be located on a right side of the compact layout, according to an example embodiment of the invention. However, it will be appreciated that the locations of the input ports and output ports may also be a varied or otherwise reassigned according to an example embodiment of the invention. For example, the input ports of the transformers may be reassigned to provide the same current flow direction of the adjacent outer sections of the primary windings. Likewise, the output ports of transformers may be reassigned to provide the same current flow direction of the adjacent outer sections of the primary windings.

As an example, FIG. 1B illustrates a compact layout where the input ports **107**, **108** for the first transformer **101** and the input ports **109**, **110** for the second transformer **102** may be provided on a left side of the respective transformers **101**, **102**. However, the output ports **107**, **108** for the first transformer **101** may be relocated to a top side of the first transformer **101** while the output ports **109**, **110** for the second transformer **102** may be relocated to a bottom side of the second transformer **102**. As another example, FIG. 1C illustrates a compact layout where the input ports **103**, **104** for the first transformer **101** may be provided on a top side of the first transformer **101** while the input ports **105**, **106** may be provided on a bottom side of the second transformer **102**. The

output ports **107**, **108** for the first transformer **101** as well as the output ports **109**, **110** may be placed on a right side of the respective transformers **101**, **102**. It will be the input ports and the output ports may be reassigned to various other locations without departing from example embodiments of the invention.

According to an example embodiment of the invention, the first and second transformers **101**, **102** may have substantially symmetrical or mirrored structures. The symmetrical or mirrored structures may provide for good balancing of signals, according to an example embodiment of the invention. In an example embodiment of the invention, the line of symmetry may be defined according to a line between the adjacent sections of the first transformers **101**, **102**.

FIG. 2 illustrates an example application for compact multiple transformers, according to an example embodiment of the invention. In FIG. 2, there may be a plurality of amplifier blocks **241**, **242**, **243**. According to an example embodiment of the invention, the amplifiers blocks **241**, **242**, **243** may be provided as parallel blocks.

The first amplifier block **241** may include a first-stage amplifier **211**, a transformer **207**, and a second-stage amplifier **212**, according to an example embodiment of the invention. Likewise, the amplifier block **242** may include a first-stage amplifier **213**, a transformer **208**, and a second-stage amplifier **214**, according to an example embodiment of the invention. The amplifier block **243** may include a first-stage amplifier **215**, a transformer **209**, and a second-stage amplifier **216**. According to an example embodiment of the invention, the transformers **207**, **208**, **209** may be operative for inter-stage matching between a first and second electronic circuit blocks or first and second radio frequency (RF) circuit blocks. For example, the transformers **207**, **208**, **209** may be operative for inter-stage matching between the respective first-stage amplifier **211**, **213**, **215** and the respective second-stage amplifier **212**, **214**, **216**, according to an example embodiment of the invention.

In FIG. 2, the first transformer **207** may be comprised of a primary winding **201** that encapsulates or surrounds one or more sections of the secondary winding **202**. The second transformer **208** may be comprised of a primary winding **203** that encapsulates or surrounds one or more sections of the secondary winding **204**. Likewise, the third transformer **209** may be comprised of a primary winding **205** that encapsulates or surrounds one or more sections of the secondary winding **206**.

As shown in FIG. 2, the transformers **207**, **208**, **209** may be positioned according using compact layout in which the first transformer **207** and the third transformer **209** may sandwich the second transformer **208**. According to an example embodiment of the invention, the separation distance between the adjacent sections of the primary windings **201**, **203**, **205** may be minimized to provide the compact layout. For example, the separation distance between adjacent sections of primary windings **201**, **203**, **205** may be less than 50 μm , perhaps in the range of minimum spacing to 15 μm (e.g., perhaps 0.01-6 μm) for a highly compact layout or in the range of 15-30 μm (e.g., perhaps 12-14 μm) for a slightly less compact layout. Other spacing ranges may also be utilized without departing from example embodiments of the invention.

In FIG. 2, the bottom section of the first primary winding **201** may have the same linear current flow direction (e.g., right-to-left current flow) as the top section of the second primary winding **203**. Thus, the bottom section of the first primary winding **201** may be magnetically coupled to the top section of the second primary winding **203**, according to an

example embodiment of the invention. Similarly, the bottom section of the second primary winding **208** may have the same linear current flow direction (e.g., left-to-right current flow) as the top section of the third primary winding **205**. Accordingly, the bottom section of the second primary winding **203** may be magnetically coupled to the top section of the third primary winding **205**.

As discussed above, the primary winding **203** of the second transformer **208** may be magnetically coupled to both the first and third transformers **207**, **209**. However, to do so, the primary winding **203** of the second transformer may be provided with a first rotational current flow direction while the primary windings **201**, **205** of the first and third transformers **207**, **209** may be provided with a second rotational current flow direction different from or opposite the first rotational current flow direction. For example, the second primary winding **203** may be provided with a counterclockwise rotational current flow direction, thereby providing for a right-to-left linear current flow direction in its top section and a left-to-right linear current flow in its bottom section, according to an example embodiment of the invention. On the other hand, the first and third primary windings **201**, **205** may be provided with a clockwise rotational current flow direction, thereby providing for a left-to-right linear current flow direction in their respective top sections and a right-to-left linear current flow direction in their respective bottom sections.

It will be appreciated that in order to provide the second primary winding **203** with first rotational current flow direction (e.g., counterclockwise), the first input port **222** may be connected to a negative input signal while the second input port **223** may be connected a positive input signal. On the other hand, the first input ports **220**, **224** and the second input ports **221**, **225** for the first and third primary windings **201**, **205** may be connected with an opposite polarities than that for the second primary winding **203**. For example, the first input ports **220**, **224** may be connected to a positive input signal while the second input ports **221**, **225** may be connected to a negative input signal. According to an example embodiment of the invention, the first-stage amplifiers **211**, **213**, **215** may be connected such as to provide the required negative or positive input signals to the respective first input ports **220**, **222**, **224** and second input ports **221**, **223**, **225**.

Still referring to FIG. 2, the first output port **228** for the second transformer **208** may be provided with a negative output signal while the second output port **229** may be provided with a positive output signal, according to an example embodiment of the invention. On the other hand, the first output ports **226**, **230** for the first and third transformers **207**, **209** may be provided with a positive output signal while the second output ports **227**, **231** may be provided with a negative output signal, according to an example embodiment of the invention. The second-stage amplifiers **212**, **214**, **216** may receive the negative or positive output signals from the respective first output ports **226**, **228**, **230** and second output ports **227**, **229**, **231**. Thus, it will be appreciated that the input and output ports of the amplifiers may be reassigned according to current flow direction desired by the transformers, according to an example embodiment of the invention.

FIG. 3 illustrates example compact multiple transformers with multi-turn windings, according to an example embodiment of the invention. In particular, FIG. 3 illustrates a first transformer **305** and a second transformer **306**. The first transformer **305** may include a primary multi-turn winding **301** (e.g., 2 or more turns) and a secondary multi-turn winding **302** (e.g., 2 or more turns), according to an example embodiment of the invention. The primary multi-turn winding **301** may include a plurality of inner and outer sections **301a-c** that

may be connected by one or more wire-bond, via, or other electrical connections, according to an example embodiment of the invention. The secondary multi-turn winding **302** may include a plurality of inner and outer sections **302a-c** that may be connected by one or more wire-bond, via, or other electrical connections, according to an example embodiment of the invention. Similarly, the second transformer **306** may include a primary multi-turn winding **303** (e.g., 2 or more turns) and a secondary multi-turn winding **304** (e.g., 2 or more turns), according to an example embodiment of the invention. The primary multi-turn winding **303** may include a plurality of inner and outer sections **303a-c** that may be connected by one or more wire-bond, via, or other electrical connections, according to an example embodiment of the invention. The secondary multi-turn winding **304** may include a plurality of inner and outer sections **304a-c** that may be connected by one or more wire-bond, via, or other electrical connections, according to an example embodiment of the invention.

According to an example embodiment of the invention, the spacing between the adjacent sections **301b**, **303a** of the primary multi-turn windings **301**, **303** may be minimized to provide a compact layout. For example, the spacing between the adjacent sections **301b**, **303a** may be less than 50 μm , perhaps in the range of minimum spacing to 15 μm (e.g., perhaps 0.01-6 μm) for a highly compact layout or in the range of 15-30 μm (e.g., perhaps 12-14 μm) for a slightly less compact layout. Other spacing ranges may also be utilized without departing from example embodiments of the invention.

In FIG. 3, the multi-turn primary winding **301** may be provided with a first rotational current direction (e.g., counterclockwise) when the multi-turn primary winding **303** may be provided with a second rotational current direction (e.g., clockwise) that is opposite the first rotational direction. Accordingly, when the bottom section **301b** of the multi-turn primary winding **301** may have a linear current flow direction (e.g., left to right) that may be the same as that for the top section **303a** of the multi-turn primary winding **303**. According to an example embodiment of the invention, the bottom section **301b** and the top section **303a** may be magnetically coupled to each other.

In order to provide the first multi-turn primary winding **301** with the first rotational current direction, the primary multi-turn winding **301** may receive input signals from a first input port **310** that receives a negative input signal and a second input port **311** that receives a positive input signal. The secondary multi-turn winding **302** may provide output signals at a first output port **320** providing a negative output signal and a second output port **321** providing a positive output signal, according to an example embodiment of the invention.

On the other hand, in order to provide the second multi-turn primary winding **303** with the second rotational current direction opposite the first rotational current direction, the primary multi-turn winding **303** may receive input signals from a first input port **312** that receives a positive input signal and a second input port **313** that receives a negative input signal. The secondary multi-turn winding **304** may provide output signals at a first output port **322** providing a positive output signal and a second output port **323** providing a negative output signal. It will be appreciated that the input ports and the output ports may be reassigned to various other locations without departing from example embodiments of the invention.

FIG. 4 illustrates the compact layout of FIG. 1A where the multiple transformers are provided with DC feeds through center tap ports, according to an example embodiment of the invention. As shown in FIG. 4, each primary winding **111**,

113 may include a respective center tap port **401**, **402**. Likewise, each secondary winding **112**, **114** may include a respective center tap port **403**, **404**. The center tap ports **401**, **402**, **403**, **404** may be at virtual AC grounds when differential signals are provided to respective input ports **103**, **104** and **105**, **106**. According to an example embodiment of the invention, one or more respective DC bias voltages **411-414** may be fed through the one or more respective center tap ports **401-404**. According to an example embodiment of the invention, the positions of the center tap ports **401-404** may correspond to a middle or symmetrical position of the respective primary windings **111**, **113** or secondary winding **112**, **114**. However, in another example embodiment of the invention, the positions of the center tap ports **401-404** may vary from a middle or symmetrical position as well.

FIG. 5 illustrates the example compact multiple transformers of FIG. 1A, where the multiple transformers may be provided with tuning blocks through center tap ports, according to an example embodiment of the invention. As shown in FIG. 5, each primary winding **111**, **113** may include a respective center tap port **501**, **502**. Likewise, each secondary winding **112**, **114** may include a respective center tap port **503**, **504**. The center tap ports **501**, **502**, **503**, **504** may be at virtual AC grounds when differential signals are provided to respective input ports **103**, **104** and **105**, **106**. According to an example embodiment of the invention, one or more tuning blocks **511**, **512**, **513**, **514** may be provided to the respective windings **501-504** through respective center tap ports **501-504**. According to an example embodiment of the invention, one or more tuning blocks **511-514** may be utilized to tune the frequency characteristics of the transformers **101**, **102**. For example, the tuning blocks **511-514** may be operative to control, adjust, filter, or otherwise tune the frequency bands of coupling, according to an example embodiment of the invention. As another example, the tuning blocks **511-514** may be resonant circuits that are operative to selectively enhance or suppress one or more frequency components, according to an example embodiment of the invention. According to an example embodiment of the invention, the tuning blocks **511-514** may have arbitrary complex impedances from 0 to infinity for one or more frequency bands.

FIG. 6A is a schematic diagram of an example tuning block, according to an example embodiment of the invention. As shown in FIG. 6A, the tuning block may be a resonant circuit comprised of a capacitive component **601** and an inductive component **602** connected in series, according to an example embodiment of the invention. The port **600** of the resonant circuit may be connected to a center tap port of a primary and/or a secondary winding, according to an example embodiment of the invention. The resonant circuit of FIG. 6A may have an associated resonant frequency f_n **603**, according to an example embodiment of the invention.

FIG. 6B illustrates another schematic diagram of an example tuning block, according to an example embodiment of the invention. As shown in FIG. 6B, the tuning block may be a resonant circuit comprised of a capacitive component **611** in parallel with an inductive component **612**. The port **610** of the resonant circuit may be connected to a center tap port of a primary and/or a secondary winding, according to an example embodiment of the invention. The resonant circuit may have a resonant frequency f_n **613**, according to an example embodiment of the invention.

FIG. 6C illustrates another schematic diagram of an example tuning block, according to an example embodiment of the invention. As shown in FIG. 6C, there may be a resonant circuit having a plurality of resonant frequencies such as resonant frequencies f_{n1} **627**, f_{n2} **628**, and f_{n3} **629**. For

example, capacitive component **621** and inductive component **622** may be connected in series to provide resonant frequency **fn1 627**. Likewise, capacitive component **623** may be connected in series to inductive component **624** to provide resonant frequency **fn2 628**. Additionally, capacitive component **625** may be connected in series with inductive component **626** to provide resonant frequency **fn3 629**. The port **620** of the resonant circuit may be connected to a center tap port of a primary and/or a secondary winding, according to an example embodiment of the invention. It will be appreciated that while FIG. **6C** illustrates a particular configuration for a resonant circuit, other embodiments of the invention may include varying types of series/parallel resonant circuits without departing from example embodiments of the invention. Furthermore, while the tuning blocks are illustrated as being connected at the center tap ports, other embodiments of the invention may connect the tuning blocks to the primary windings in other locations as well.

It will be appreciated that the values and parameters of the capacitive and inductive components of FIGS. **6A-6C** may be selected to have one or more desired resonant frequencies. Furthermore, the resonant circuits may also include resistive components as well. According to an example embodiment of the invention, the one or more resonant frequencies of the tuning block may be operative to filter undesirable harmonics or enhance other harmonics at the one or more resonant frequencies, thereby controlling the frequencies of coupling. The one or more tuning blocks can also be used to modify or provide a delay or frequency adjustment needed to synchronize the input or output signals, according to an example embodiment of the invention.

According to an example embodiment of the invention, the layouts for the transformers described herein may be implemented utilizing a planar structure or a stacked structure. With a planar structure, the plurality of transformers may be placed substantially in the same metal layer. For example, as shown in the example planar substrate structure of FIG. **7**, the plurality of transformers may all be fabricated on the same first metal layer **702**. Routing between input and output ports or between sections of the primary/secondary winding may be accomplished using one or more via, wire-bond, or other electrical connections, according to an example embodiment of the invention.

According to another example embodiment of the invention, the layouts for the transformers may also be implemented utilizing a stacked structure. For example, in the stacked substrate structure of FIG. **8**, a first transformer may be formed on metal layer **802** while a second transformer may be formed on metal layer **804**, according to an example embodiment of the invention. Routing between input and output ports or between sections of the primary/secondary winding may be accomplished using one or more via, wire-bond, or other electrical connections, according to an example embodiment of the invention. It will be appreciated that the example layouts may also be applied to the overlapping multiple transformers described herein.

FIGS. **9A-9C** illustrate several example embodiments of overlapping compact multiple transformers, according to an example embodiment of the invention. These overlapping compact multiple transformers include a plurality of transformer sections, each with at least one respective primary winding section and at least one respective secondary winding. However, a primary winding section of one transformer section may have a portion that is electrically shared or overlapping with a primary winding section of an adjacent transformer section. With shared or overlapping portions (which may also be referred to as common portions), there may be a

common current flow that is shared between the primary winding sections of the adjacent transformer sections. Due to the shared or overlapping portions, an improved impedance transition efficiency may be provided by the overlapping compact multiple transformers. It will be appreciated that while FIGS. **9A-9C** illustrate only two transformer sections, the shared or overlapping portions can equally be applied to more than two transformer sections, as illustrated with respect to FIGS. **10A, 10B, and 11**.

Turning now to FIG. **9A**, the overlapping multiple transformers can be implemented using a first transformer section **901** and a second transformer section **902**, according to an example embodiment of the invention. As shown in FIG. **9A**, the example overlapping multiple transformers may include a first transformer section **901** that includes a primary winding section **911** and a secondary winding **912**. The primary winding section **911** may receive input signals from a first input port **903** that may receive a positive input signal and a second input port **904** that may receive a negative input signal. According to an example embodiment of the invention, the primary winding section **911** may be inductively coupled to the secondary winding **912**. The secondary winding **912** may provide output signals to a first output port **907** providing a positive output signal and a second output port **908** providing a negative output signal. As shown in FIG. **9A**, the outer primary winding section **911** may encapsulate or surround one or more portions of the inner secondary winding **912**, which may include encapsulating a portion or substantially all of the inner secondary winding **912**. One or more wire-bond, via, or other electrical connections **920a, 920b** may be used to route or provide the output ports **907, 908** of the secondary winding **912** around the primary winding section **911**. For example, connection **920a** may be used to electrically connect a first portion of the secondary winding **912** to the first output port **907**, and connection **920b** may be used to electrically connect a second portion of the secondary winding **912** to the second output port **908**.

Similarly, the example compact multiple transformers of FIG. **9A** may also include a second transformer section **902** that may include a primary winding section **913** and a secondary winding **914**. The primary winding section **913** may receive input signals from a first input port **905** that may receive a negative input signal and a second input port **906** that may receive a positive input signal. According to an example embodiment of the invention, the primary winding section **913** may be inductively coupled to the secondary winding **914**. The secondary winding **914** may provide output signals to a first output port **909** providing a positive signal output and a second output port **910** providing a negative signal output. As shown in FIG. **9A**, the outer primary winding section **913** may encapsulate or surround one or more portions of the inner secondary winding **914**, which may include encapsulating a portion or substantially all of the inner secondary winding **914**. One or more wire-bond, via, or other electrical connections **921a, 921b** may be used to route the output ports **909, 910** of the secondary winding **914** around the primary winding section **913**. For example, connection **921a** may be used to electrically connect a first portion of the secondary winding **914** to the first output port **909**, and connection **921b** may be used to electrically connect a second portion of the secondary winding **914** to the second output port **910**.

According to an example embodiment of the invention, the first transformer section **901** and the second transformer section **902** may be spiral-type transformers, although other types of transformers may be utilized as well. It will also be appreciated that the primary winding sections **911, 913** and

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the secondary windings **912**, **914** may be fabricated or otherwise patterned as conductive lines or traces using one or more metal layers provided on one or more semiconductor substrates. As an example, the metal layers may be comprised of copper, gold, silver, aluminum, nickel, a combination thereof, or yet other conductors, metals, and alloys, according to an example embodiment of the invention. According to an example embodiment of the invention, the transformer sections **901**, **902** may be fabricated with other devices on the same substrate. For example, transistors, inductors, capacitors, resistors, and transmission lines may be fabricated with the transformer sections **901**, **902** on the same substrate.

In FIG. **9A**, the first transformer section **901** and the second transformer section **902** may be placed adjacent to each other according to an overlapping compact layout, according to an example embodiment of the invention. For example, a first section (e.g., a bottom section) of the primary winding section **911** may be placed adjacent to, or may be common with, a second section (e.g., a top section) of the primary winding section **913** with zero separation distance (or otherwise forming a same section), to provide a shared or common portion **915**. In other words, the primary winding sections **911** and **913** may include a shared or common portion **915**, which may provide for a common current flow through the shared or common portion **915**. Because there is a common current flow through the shared or common portion **915**, it may be preferable in an example embodiment for the primary winding sections **911**, **913** to be positioned relative to each other such that current or flux of each of the primary winding sections **911**, **913** are summed in phase through the shared or common portion **915**. It will be appreciated that the shared or common portion **915** can be characterized or implemented as two adjacent portions of the primary winding sections **911** and **913** that have zero separation distance (or otherwise forming a same section), or that are otherwise electrically connected to each other in a lateral matter or a vertical/overlapping manner. For example, the two adjacent portions of the primary winding sections **911**, **913** can be electrically fused together (e.g., conductive adhesive, solder, etc.) or configured to electrically overlap to provide the shared or common portion **915**.

As shown in FIG. **9A**, there may be a common current flow through the shared or common portion **915**. In order to all the current or flux of each of the primary winding sections **911**, **913** to be summed in phase through the shared or common portion **915**, the rotational current flow in the primary winding section **911** may be provided in a first rotational direction while the rotational current flow in the primary winding section **913** may be provided in a second rotational direction that is different from or opposite the first rotational direction. For example, by providing the primary winding section **911** with a clockwise rotational current flow direction, the linear current flow in the shared or common portion **915** of the primary winding section **911** may be a right-to-left linear current flow direction. The shared or common portion **915** of the primary winding section **913** may likewise be provided with a right-to-left linear current flow direction by providing the primary winding section **913** with a counterclockwise rotational current flow direction. Because the primary winding sections **911** and **913** are electrically connected by way of a shared or common portion **915**, the primary winding sections **911** and **913** can also be characterized as forming a single, meandering primary winding that is inductively coupled to respective secondary windings **912**, **914** (at respective sections **911** and **913**), according to an example embodiment of the invention.

It will be appreciated that to provide the appropriate current flow directions described herein, the appropriate polarity (+

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or -) signals will need to be provided to ports **903**, **904** of the primary winding section **911**, as well as to ports **905**, **906** of the primary winding section **913**. For example, to provide the primary winding section **911** with the clockwise rotational current flow direction, the first input port **903** may be provided with a positive input signal and the second input port **904** may be provided with a negative input signal, according to an example embodiment of the invention. On the other hand, to provide the primary winding **905** with the counterclockwise rotational current flow direction, the first input port **905** may be provided with a negative input signal and the second input port **906** may be provided with a positive input signal, according to an example embodiment of the invention.

In FIG. **9A**, both the input ports **903**, **904** for the first transformer section **901** as well as the input ports **905**, **906** for the second transformer section **902** may be located on a left side of a compact layout according to an example embodiment of the invention. Furthermore, it will be appreciated that the ports **903-906** may be provided in a sequential positive/negative/negative/positive configuration, respectively instead of the typical alternating positive and negative configuration. The two adjacent negative input ports **904**, **905**, as sandwiched by the exterior positive input ports **903**, **906**, may be preferable in some example embodiments to facilitate the routing to appropriate connections to one or more amplifiers or other devices, or to otherwise maintain an appropriate synchronization and/or delay of positive and negative signals. The output ports **907**, **908** for the first transformer section **901** as well as the output ports **909**, **910** for the second transformer section **902** may be located on a right side of the compact layout, according to an example embodiment of the invention. Again, it will be appreciated that the ports **907-910** may be provided in a sequential positive/negative/negative/positive configuration, respectively instead of the typical alternating positive and negative configuration, according to an example embodiment of the invention. The two adjacent negative output ports **908**, **909**, as sandwiched by the exterior positive output ports **907**, **910**, may be preferable in some example embodiments to facilitate the routing to appropriate connections to one or more amplifiers or other devices, or to otherwise maintain an appropriate synchronization and/or delay of positive and negative signals, according to an example embodiment of the invention.

It will be appreciated that the locations of the input ports and output ports shown in FIG. **9A** may also be a varied or otherwise reassigned according to an example embodiment of the invention. For example, the input ports of the transformers may be reassigned to provide the same current flow direction of the adjacent outer sections of the primary windings. Likewise, the output ports of transformers may be reassigned to provide the same current flow direction of the adjacent outer sections of the primary windings.

As an example, FIG. **9B** illustrates a compact layout where the input ports **907**, **908** for the first transformer section **901** and the input ports **909**, **910** for the second transformer section **902** may be provided on a left side of the respective transformer sections **901**, **902**. However, the output ports **907**, **908** for the first transformer section **901** may be relocated to a top side of the first transformer section **901** while the output ports **909**, **910** for the second transformer section **902** may be relocated to a bottom side of the second transformer section **902**. As another example, FIG. **9C** illustrates a compact layout where the input ports **903**, **904** for the first transformer section **901** may be provided on a top side of the first transformer section **901** while the input ports **905**, **906** may be provided on a bottom side of the second transformer section **902**. The output ports **907**, **908** for the first transformer sec-

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tion **901** as well as the output ports **909, 910** may be placed on a right side of the respective transformer sections **901, 902**. It will be the input ports and the output ports may be reassigned to various other locations without departing from example embodiments of the invention.

According to an example embodiment of the invention, the first and second transformer sections **901, 902** may have substantially symmetrical or mirrored structures. The symmetrical or mirrored structures may provide for good balancing of signals, according to an example embodiment of the invention. In an example embodiment of the invention, the line of symmetry may be defined according to a line following the common or shared portion **915** of the first transformer sections **901, 902**.

FIG. **10A** illustrates an example application for overlapping multiple transformers, according to an example embodiment of the invention. In FIG. **10A**, there may be a plurality of amplifying sections **1041, 1042, 1043**. According to an example embodiment of the invention, the amplifying sections **1041, 1042, 1043** may be provided as parallel sections.

The first amplifying section **1041** may include a first-stage amplifier **1011**, a transformer section **1007**, and a second-stage amplifier **1012**, according to an example embodiment of the invention. Likewise, the second amplifying section **1042** may include a first-stage amplifier **1013**, a transformer section **1008**, and a second-stage amplifier **1014**, according to an example embodiment of the invention. The third amplifying section **1043** may include a first-stage amplifier **1015**, a transformer section **1009**, and a second-stage amplifier **1016**. According to an example embodiment of the invention, the transformer sections **1007, 1008, 1009** may be operative for inter-stage matching between first and second electronic circuit blocks or between first and second RF circuit blocks. For example, the transformer sections **1007, 1008, 1009** may be operative for inter-stage matching between the respective first-stage amplifier **1011, 1013, 1015** and the respective second-stage amplifier **1012, 1014, 1016**, according to an example embodiment of the invention.

In FIG. **10A**, the first transformer section **1007** may be comprised of a primary winding section **1001** that encapsulates or surrounds one or more sections of the secondary winding **1002**, which may include encapsulating a portion or substantially all of the secondary winding **1002**. The second transformer section **1008** may be comprised of a primary winding section **1003** that encapsulates or surrounds one or more sections of the secondary winding **1004**, which may include encapsulating a portion or substantially all of the secondary winding **1004**. Likewise, the third transformer section **1009** may be comprised of a primary winding section **1005** that encapsulates or surrounds one or more sections of the secondary winding **1006**, which may include encapsulating a portion or all substantially all of the secondary winding **1006**.

As shown in FIG. **10A**, the transformer sections **1007, 1008, 1009** may be positioned adjacent to each other according to an overlapping compact layout, according to an example embodiment of the invention. Indeed, the first and third transformer sections **1007, 1009** may sandwich the second transformer section **1008**. For example, a first section (e.g., a bottom section) of the first primary winding section **1001** may be placed adjacent to, or may be common with, a second section (e.g., a top section) of the second primary winding section **1003** with zero separation distance (or otherwise forming a same section), to provide a shared or common portion **1050a**. In other words, the primary winding sections **1001** and **1003** may include a shared or common portion **1050a**, which may provide for a common current flow

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through the shared or common portion **1050a**. Furthermore, a third section (e.g., a bottom section) of the second primary winding section **1003** may be placed adjacent to, or may be common with, a fourth section (e.g., a top section) of the third primary winding section **1005** with zero separation distance (or otherwise forming a same section), to provide a shared or common portion **1050b**. In other words, the primary winding sections **1001** and **1003** may include a shared or common portion **1050b**, which may provide for a common current flow through the shared or common portion **1050b**.

Because there is a common current flow through the shared or common portion **1050a**, it may be preferable in an example embodiment for the primary winding sections **1001, 1003** to be positioned relative to each other such that current or flux of each of the primary winding sections **1001, 1003** are summed in phase through the shared or common portion **1050a**. Likewise, because there is a common current flow through the shared or common portion **1050b**, it may be preferable in an example embodiment for the primary winding sections **1003, 1005** to be positioned relative to each other such that current or flux of each of the primary winding sections **1003, 1005** are summed in phase through the shared or common portion **1050b**. It will be appreciated that the shared or common portion **1050a** can each be characterized or implemented as two adjacent portions of the primary winding sections **1001** and **1003** that have zero separation distance (or otherwise forming a same section), or that are otherwise electrically connected to each other in a lateral matter or a vertical/overlapping manner. Similarly, the shared or common portion **1050b** can each be characterized or implemented as two adjacent portions of the primary winding sections **1003** and **1005** that have zero separation distance (or otherwise forming a same section), or that are otherwise electrically connected to each other in a lateral matter or a vertical/overlapping manner. For example, the two adjacent portions of the primary winding sections **1001, 1003** can be electrically fused together (e.g., conductive adhesive, solder, etc.) or configured to electrically overlap to provide the shared or common portion **1050a**. Similarly, the two adjacent portions of the primary winding sections **1003, 1005** can be electrically fused together (e.g., conductive adhesive, solder, etc.) or configured to electrically overlap to provide the shared or common portion **1050b**.

In FIG. **10A**, the bottom section of the first primary winding section **1001** may have the same linear current flow direction (e.g., right-to-left current flow) as the top section of the second primary winding section **1003**, as a common current flows through the shared or common portion **1050a**. Thus, the bottom section of the first primary winding section **1001** may be electrically coupled to, or may be common with, the top section of the second primary winding section **1003**, according to an example embodiment of the invention. Similarly, the bottom section of the second primary winding section **1003** may have the same linear current flow direction (e.g., left-to-right current flow) as the top section of the third primary winding section **1005**, as a common current flows through the shared or common portion **1050b**. Accordingly, the bottom section of the second primary winding section **1003** may be electrically coupled to, or may be common with, the top section of the third primary winding section **1005**.

As discussed herein, the primary winding section **1003** of the second transformer section **1008** may be coupled to both the first and third transformer sections **1007, 1009** via the respective shared or common portions **1050a, 1050b**. To ensure that flux or current is summed in the shared or common portions **1050a, 1050b**, the primary winding section **1003** of the second transformer may be provided with a first rotational

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current flow direction while the primary winding sections **1001**, **1005** of the first and third transformers **1007**, **1009** may be provided with a second rotational current flow direction different from or opposite the first rotational current flow direction. For example, the second primary winding section **1003** may be provided with a counterclockwise rotational current flow direction, thereby providing for a right-to-left linear current flow direction in its top section (corresponding to the shared or common portion **1050a**) and a left-to-right linear current flow in its bottom section (corresponding to the shared or common portion **1050b**), according to an example embodiment of the invention. On the other hand, the first and third primary winding sections **1001**, **1005** may be provided with a clockwise rotational current flow direction, thereby providing for a left-to-right linear current flow direction in their respective top sections (corresponding to shared or common section **1050b** for the third primary winding section **1005**) and a right-to-left linear current flow direction in their respective bottom sections (corresponding to shared or common section **1050a** for the first primary winding section **1001**).

It will be appreciated that in order to provide the second primary winding section **1003** with first rotational current flow direction (e.g., counterclockwise), the first input port **1022** may be connected to a negative input signal while the second input port **1023** may be connected a positive input signal. On the other hand, the first input ports **1020**, **1024** and the second input ports **1021**, **1025** for the first and third primary winding sections **1001**, **1005** may be connected with an opposite polarities than that for the second primary winding section **1003**. For example, the first input ports **1020**, **1024** may be connected to a positive input signal while the second input ports **1021**, **1025** may be connected to a negative input signal. According to an example embodiment of the invention, the first-stage amplifiers **1011**, **1013**, **1015** may be connected such as to provide the required negative or positive input signals to the respective first input ports **1020**, **1022**, **1024** and second input ports **1021**, **1023**, **1025**.

Still referring to FIG. **10A**, the first output port **1028** for the second transformer section **1008** may provide a negative output signal while the second output port **1029** may provide a positive output signal, according to an example embodiment of the invention. On the other hand, the first output ports **1026**, **1030** for the first and third transformers **1007**, **1009** may provide a positive output signal while the second output ports **1027**, **1031** may provide a negative output signal, according to an example embodiment of the invention. The second-stage amplifiers **1012**, **1014**, **1016** may receive the negative or positive output signals from the respective first output ports **1026**, **1028**, **1030** and second output ports **1027**, **1029**, **1031**.

The two adjacent negative input ports **1021**, **1022** (sandwiched by positive ports **1020**, **1023**), as well as the two adjacent positive input ports **1023**, **1024** (sandwiched by negative ports **1022**, **1025**) may be preferable in some example embodiments to facilitate the routing to appropriate connections to one or more amplifiers **1011**, **1013**, **1015** or other devices, or to otherwise maintain an appropriate synchronization and/or delay of positive and negative signals. Likewise, the two adjacent negative output ports **1027**, **1028** (sandwiched by positive ports **1026**, **1029**), as well as the two adjacent positive output ports **1029**, **1030** (sandwiched by negative ports **1028**, **1031**) may be preferable in some example embodiments to facilitate the routing to appropriate connections to one or more amplifiers **1012**, **1014**, **1016** or other devices, or to otherwise maintain an appropriate synchronization and/or delay of positive and negative signals. It will also be appreciated that the input and output ports of the

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amplifiers may be reassigned according to current flow direction desired by the transformers, according to an example embodiment of the invention.

FIG. **10B** illustrates an alternative application for the compact multiple transformers described with respect to FIG. **10A**. In particular, FIG. **10A** still illustrates three transformer sections **1061**, **1062**, **1063**. However, in FIG. **10B**, each of the three transformer sections **1061**, **1062**, **1063** share one or more common amplifiers **1060**. More specifically, the positive input ports **1020**, **1023**, and **1024** may receive a positive signal from the output of one or more common amplifiers **1060**. Similarly, the negative input ports **1021**, **1022**, and **1025** may receive a negative signal from the output of one or more common amplifiers **1060**. It will be appreciated that the routing connections from the ports **1020**-**1025** to the power amplifier **1060** may be implemented using a variety of ways, according to an example embodiment of the invention. Likewise, while not illustrated in FIG. **10B**, the amplifiers **1012**, **1014**, **1016** could also be replaced with one or more common amplifiers and similar routing connections, according to an example embodiment of the invention.

While not described in detail with respect to FIGS. **9A**, **9B**, **9C**, and **10**, it will be appreciated that one or more of the primary winding segments or secondary winding may include a respective center tap port, as similarly described herein. The center tap ports can be used to provide a DC bias feed to one or more amplifiers or other devices. Likewise, the center tap ports can be used to connect to one or more tuning blocks such as those described with respect to FIGS. **6A**-**6C**. The one or more tuning blocks can be used to filter undesirable harmonics or enhance other harmonics at the one or more resonant frequencies, thereby controlling the frequencies of coupling. The one or more tuning blocks can also be used to modify or provide a delay or frequency adjustment needed to synchronize the input or output signals, according to an example embodiment of the invention.

FIG. **11** illustrates an example system for overlapping multiple transformers, according to an example embodiment of the invention. The example system may include a first transformer section **1107**, a second transformer section **1108**, and a third transformer section **1109**.

In FIG. **11**, the first transformer section **1107** may be comprised of a primary winding section **1101** that encapsulates or surrounds one or more sections of the secondary winding **1102**, which may include encapsulating a portion or substantially all of the secondary winding **1102**. The second transformer section **1108** may be comprised of a primary winding section **1103** that encapsulates or surrounds one or more sections of the secondary winding **1104**, which may include encapsulating a portion or substantially all of the secondary winding **1104**. Likewise, the third transformer section **1109** may be comprised of a primary winding section **1105** that encapsulates or surrounds one or more sections of the secondary winding **1106**, which may include encapsulating a portion or substantially all of the secondary winding **1106**.

The transformer sections **1107**, **1108**, **1109** may be positioned adjacent to each other according to an overlapping compact layout, according to an example embodiment of the invention. Indeed, the first and third transformer sections **1107**, **1109** may sandwich the second transformer section **1108**. For example, a first section (e.g., a right section) of the first primary winding section **1101** and a second section (e.g., a left section) of the second primary winding section **1103** may the same shared or common portion **1150a**. In other words, the primary winding sections **1101** and **1103** may include a shared or common portion **1150a**, which may provide for a common current flow through the shared or com-

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mon portion 1150a. Furthermore, a third section (e.g., a right section) of the second primary winding section 1103 and a fourth section (e.g., a left section) of the third primary winding section 1105 may be a same shared or common portion 1150b. In other words, the primary winding sections 1101 and 1103 may include a shared or common portion 1150b, which may provide for a common current flow through the shared or common portion 1150b.

Because there is a common current flow through the shared or common portion 1150a, it may be preferable in an example embodiment for the primary winding sections 1101, 1103 to be positioned relative to each other such that current or flux of each of the primary winding sections 1101, 1103 are summed in phase through the shared or common portion 1150a. Likewise, because there is a common current flow through the shared or common portion 1150b, it may be preferable in an example embodiment for the primary winding sections 1103, 1105 to be positioned relative to each other such that current or flux of each of the primary winding sections 1103, 1105 are summed in phase through the shared or common portion 1150b. It will be appreciated that the shared or common portion 1150a can each be characterized or implemented as two adjacent portions of the primary winding sections 1101 and 1103 that have zero separation distance (or otherwise forming a same section), or that are otherwise electrically connected to each other in a lateral matter or a vertical/overlapping manner. Similarly, the shared or common portion 1150b can each be characterized or implemented as two adjacent portions of the primary winding sections 1103 and 1105 that have zero separation distance (or otherwise forming a same section), or that are otherwise electrically connected to each other in a lateral matter or a vertical/overlapping manner. For example, the two adjacent portions of the primary winding sections 1101, 1103 can be electrically fused together (e.g., conductive adhesive, solder, etc.) or configured to electrically overlap to provide the shared or common portion 1150a. Similarly, the two adjacent portions of the primary winding sections 1103, 1105 can be electrically fused together (e.g., conductive adhesive, solder, etc.) or configured to electrically overlap to provide the shared or common portion 1150b.

Still referring to FIG. 11, the first input port 1122 may be connected to a negative input signal while the second input port 1123 may be connected a positive input signal. On the other hand, the first input ports 1120, 1124 and the second input ports 1121, 1125 for the first and third primary winding sections 1101, 1105 may be connected with opposite polarities than that for the second primary winding section 1103. For example, the first input ports 1120, 1124 may be connected to a positive input signal while the second input ports 1121, 1125 may be connected to a negative input signal. It will be appreciated that the input ports 1120-1125 may be configured to receive the appropriate positive and negative signals in order to facilitate the appropriate flow of current in a constructive manner through shared or common portions 1150a, 1150b, according to an example embodiment of the invention. It will also be appreciated that the positive ports 1120, 1123, and 1124 may be commonly connected to a positive system port 1160, while the negative ports 1121, 1122, and 1125 may be commonly connected to a negative system port 1161 without departing from example embodiments of the invention. As such one or more common amplifiers or other devices can provide the respective positive and negative signal to the respective positive system port 1160 and negative system port 1161. However, it will also be appreciated that respective amplifiers or other devices can also be provided to the input ports for each respective transformer

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section 1107, 1108, and 1109 without departing from example embodiments of the invention.

Still referring to FIG. 11, the first output port 1128 for the second transformer section 1108 may provide a negative output signal while the second output port 1129 may provide a positive output signal, according to an example embodiment of the invention. On the other hand, the first output ports 1126, 1130 for the first and third transformer sections 1107, 1109 may provide a positive output signal while the second output ports 1127, 1131 may provide a negative output signal, according to an example embodiment of the invention. Respective amplifiers or other devices may be connected to the respective output ports of each transformer section 1107, 1108, 1109; however, there may be one or more common amplifiers or other devices connected to a system positive output port and a system negative output port that are connected to the respective positive and negative ports of the transformer sections 1107, 1108, 1109.

FIG. 11 also shows respective center tap ports 1171, 1172, and 1173 being connected to the respective primary winding sections 1101, 1103, 1105. As described herein, the center tap ports 1171, 1172, and 1173 may be used to provide DC biasing for one or more amplifiers or other devices, or for connection of one or more tuning blocks, perhaps one of those described with respect to FIGS. 6A-6C. If a common DC biasing or amplifier block is to be connected, there may be a common connection section 1175 utilized to electrically connect the center tap ports 1171, 1172, and 1173, according to an example embodiment of the invention. Likewise, the center tap ports can also be utilized with secondary windings 1102, 1104, 1106 without departing from example embodiments of the invention.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

What is claimed is:

1. A system for multiple transformers, comprising:

a first transformer section that includes a first primary winding section and a first secondary winding, wherein the first primary winding section is inductively coupled to the first secondary winding, wherein the first transformer section is associated with a first rotational current flow direction in the first primary winding section; and
a second transformer section that includes a second primary winding section and a second secondary winding, wherein the second primary winding section is inductively coupled to the second secondary winding, wherein the second transformer section is associated with a second rotational current flow direction opposite the first rotational current flow direction in the second primary winding section,
wherein a first portion of the first primary winding section is adjacent to a second portion of the second primary winding section, wherein the adjacent first and second portions include a substantially same first linear current flow direction.

2. The system of claim 1, wherein the adjacent first and second portions collectively provide a shared section,

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wherein the shared section electrically connects the first primary winding section and the second primary winding section.

3. The system of claim 1, wherein the shared section enables current to flow from both the first primary winding section and the second primary winding section through the shared section.

4. The system of claim 1, wherein the first and second portions collectively provide the shared section by (i) overlapping the first and second portions, (ii) positioning the first and second portions adjacent to each other with zero separation distance, or (iii) being a same portion.

5. The system of claim 1, wherein the first rotational current flow direction and the second rotational current flow direction are chosen from the group consisting of (i) a clockwise current flow direction and (ii) a counterclockwise current flow direction.

6. The system of claim 1, further comprising:

a third transformer section that includes a third primary winding section and a third secondary winding, wherein the third primary winding section is inductively coupled to the third secondary winding, wherein the third transformer section is associated with the first rotational current flow direction in the third primary winding section, wherein a third section of the third primary winding section is adjacent to a fourth section of the second primary winding section, wherein the adjacent third and fourth sections include a substantially same second linear current flow direction opposite the first linear current flow direction.

7. The system of claim 6, wherein the shared section is a first shared section, wherein the adjacent third and fourth portions collectively provide a second shared section, wherein the second shared section electrically connects the second primary winding section and the third primary winding section.

8. The system of claim 1, wherein the transformers are spiral-type transformers.

9. The system of claim 1, wherein the first and second transformer sections are operative for inter-stage matching.

10. The system of claim 1, wherein the first primary winding section, the first secondary winding, the second primary winding section, and the second secondary winding each include one or more turns.

11. The system of claim 1, wherein the first transformer section and the second transformer section are substantially symmetrical in structure.

12. The system claim 1, wherein one or more of the first primary winding section, first secondary winding, second primary winding section, and second secondary winding include center tap ports defining a virtual ground.

13. The system of claim 10, wherein one or more of the center tap ports are connected to one or more bias voltages or tuning blocks.

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14. The system of claim 13, wherein the tuning blocks comprise one or more resonant circuits for enhancing or suppressing one or more frequency components.

15. The system of claim 1, wherein the first and second transformer sections are fabricated (i) on a single metal layer according to a planar structure, or (ii) on two or more metal layers according to a stacked structure.

16. A method for providing multiple transformers, comprising:

providing a first transformer section that includes a first primary winding section and a first secondary winding, wherein the first primary winding is inductively coupled to the first secondary winding, wherein the first primary winding is coupled to one or more first input ports;

receiving a first input source at the one or more first input ports to provide a first rotational current flow direction in the first primary winding;

providing a second transformer section that includes a second primary winding section and a second secondary winding, wherein the second primary winding section is inductively coupled to the second secondary winding, wherein the second primary winding is coupled to one or more second input ports;

receiving a second input source at the one or more second input ports to provide a second rotational current flow direction opposite the first rotational current flow direction in the second primary winding section; and

positioning a first portion of the first primary winding section adjacent to a second portion of the second primary winding section, wherein the adjacent first and second portions include a substantially same first linear current flow direction.

17. The method of claim 16, wherein the first rotational current flow direction and the second rotational current flow direction are chosen from the group consisting of (i) a clockwise current flow direction and (ii) a counterclockwise current flow direction.

18. The method of claim 17, wherein the adjacent first and second portions collectively provide a shared section, wherein the shared section electrically connects the first primary winding section and the second primary winding section.

19. The method of claim 17, wherein the shared section enables current to flow from both the first primary winding section and the second primary winding section through the shared section.

20. The method of claim 17, wherein the first and second portions collectively provide the shared section by (i) overlapping the first and second portions, (ii) positioning the first and second portions adjacent to each other with zero separation distance, or (iii) being a same portion.

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